# NOTICE

**All drawings located at the end of the document.**

000046017

# Draft Final
# Corrective Measures Study/ Feasibility Study

**Rocky Flats Environmental Technology Site**
**881 Hillside Area**

**(Operable Unit No 1)**

**August 1994**

## EXECUTIVE SUMMARY

This report documents the Corrective Measures Study/Feasibility Study (CMS/FS) that was performed for the 881 Hillside Area Operable Unit 1 (OU 1) of the Rocky Flats Environmental Technology Site (RFETS) The study was conducted in accordance with the requirements of the Rocky Flats Interagency Agreement (IAG) of January 1991 This agreement was signed between the U S Department of Energy (DOE), the U S Environmental Protection Agency (EPA) and the Colorado Department of Public Health and the Environment (CDPHE) The agreement specifies that the CMS/FS shall be conducted following appropriate Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and Resource Conservation and Recovery Act (RCRA) guidance

The primary source of guidance used in the preparation of this report was EPA s *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* which outlines and describes the requirements of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) In preparing this report data on OU 1 were obtained from both the *Phase III RCRA Facility Investigation/Remedial Investigation (RFI/RI) Report* and the Rocky Flats Environmental Database System (RFEDS) directly Where appropriate the more recent RFEDS data were used to revise contaminant distribution maps and site depictions

Following standard CERCLA guidelines results of the Phase III RFI/RI report were first examined to determine primary site contaminants and exposure pathways Once these risk drivers were identified, remedial action objectives (RAOs) and preliminary remediation goals (PRGs) were developed to address risks to human health and the environment In the case of OU 1 the Environmental Evaluation (EE) portion of the Baseline Risk Assessment (BRA) did not identify any current or future risks to environmental receptors Therefore this report focuses on minimizing the risk to human receptors as identified in the Public Health Evaluation (PHE) portion of the BRA The RAOs identified for OU 1 are listed below

1) Prevent the inhalation of ingestion of and/or dermal contact with volatile organic compounds (VOCs) and inorganic contaminants in groundwater that would result

in a total excess cancer risk greater than $10^{-4}$ to $10^{-6}$ for carcinogens and/or a hazard index greater than or equal to one for non carcinogens

2) Minimize further degradation of groundwater beneath OU 1 by eliminating and/or containing residual subsurface soil dense non aqueous phase liquids (DNAPLs) to the maximum extent practicable

3) Prevent the inhalation of ingestion of and/or dermal contact with polynuclear aromatic hydrocarbons (PAHs) polychlorinated biphenyls (PCBs) and radionuclides in surface soils that would result in a total excess cancer risk greater than $10^{-4}$ to $10^{-6}$ for carcinogens and/or a hazard index greater than or equal to one for non-carcinogens

4) Prevent exposure to carcinogenic radionuclides in surface soil hotspots that would result in an excessive short-term risk to a human receptor

These RAOs presented to EPA and CDPHE in Technical Memorandum (TM) #10 were selected to address the primary risk exposure pathways identified for OU 1 the pathways associated with groundwater and surface soils Because surface soil risks already fall within the acceptable risk range of $10^{-4}$ to $10^{-6}$ and because surface soil hotspots are being addressed through a recent Proposed Action Memorandum (PAM) alternatives were not developed for this medium as the RAOs are already achieved PRGs for RAOs dealing with groundwater were identified by examining both risk- and applicable or relevant and appropriate requirement (ARAR)-based values The exposure route of groundwater ingestion resulted in the highest potential risk to a future on site resident Therefore State maximum contaminant levels (MCLs) were selected as appropriate PRGs for OU 1 groundwater

After selecting appropriate PRGs for OU 1 remedial action alternatives for groundwater were assembled that would provide various conceptual approaches for cleanup of the site The alternatives presented to EPA and CDPHE in TM #11 and selected for detailed analysis following a preliminary screening process were the following

- Alternative 0 No Action
- Alternative 1 Institutional Controls without the French Drain
- Alternative 2 Institutional Controls with the French Drain
- Alternative 3 Modified French Drain with Additional Extraction Wells

- Alternatıve 4 Groundwater Pumpıng and Soıl Vapor Extractıon (SVE)
- Alternatıve 5 Groundwater Pumpıng and SVE wıth Thermal Enhancement
- Alternatıve 6 Hot Aır Injectıon wıth Mechanıcal Mıxıng
- Alternatıve 7 Soıl Excavatıon and Groundwater Removal wıth Sump Pumps

These alternatıves were subjected to detaıled analysıs as requıred by CERCLA and the NCP [40 Code of Federal Regulatıons (CFR) 300 430] The crıterıa used to analyze the alternatıves are the followıng

- Overall protectıon of human health and the envıronment
- Complıance wıth ARARs
- Long-term effectıveness and permanence
- Reductıon of toxıcıty mobılıty or volume
- Short term effectıveness
- Implementabılıty
- Cost
- State acceptance
- Communıty acceptance

The two threshold crıterıa overall protectıon of human health and the envıronment and complıance wıth ARARs, are statutory requırements that must be satısfıed by any alternatıve ın order for ıt to be elıgıble for selectıon as the preferred remedıal actıon alternatıve The five prımary balancıng crıterıa of long term effectıveness and permanence, reductıon ın toxıcıty, mobılıty and volume, short term effectıveness ımplementabılıty, and cost are used to evaluate major performance objectıves for each alternatıve The performance of each alternatıve ın addressıng each prımary balancıng crıterıon ıs evaluated and then compared across alternatıves to assıst ın the selectıon of a preferred alternatıve

The two modıfyıng crıterıa state acceptance and communıty acceptance evaluate the potentıal acceptance of the preferred alternatıve by regulatory agencıes and the communıty These last two crıterıa are not evaluated untıl after formal publıc comment on the CMS/FS and Proposed Remedıal Actıon Plan/Proposed Plan (PRAP/PP) and are addressed ın the final Correctıve Actıon Decısıon/Record of Decısıon (CAD/ROD)

For OU 1 the detailed analysis of alternatives demonstrates that Alternative 1 Institutional Controls without the French Drain is the preferred alternative for groundwater remediation This alternative consists of institutional controls to prevent unauthorized access to the 881 Hillside area and discontinuing use of the existing french drain system Groundwater modeling conducted to support the CMS/FS indicates that under this alternative the PRGs (MCLs) will not be exceeded at Woman Creek for OU 1 contaminants of concern (COCs) This alternative results in one of the lowest overall costs, while still achieving a residual risk level of 1 99 x $10^{-6}$ at this location The associated peak concentration predicted for PCE (the selected indicator chemical) is 3 60 x $10^{-3}$ mg/ℓ This is below its respective MCL of 5 x $10^{-3}$ mg/ℓ

These values are considered extremely conservative based on the assumptions used in the groundwater model (as discussed in Appendix B) Several significant loss mechanisms are currently not included in the model which tends to overestimate actual future predicted concentrations In particular volatilization a significant loss mechanism for the volatile organic compounds (VOCs) identified as COCs for OU 1 would reduce the concentrations of these contaminants prior to reaching Woman Creek The retardation and biodegradation factors used in the model are also extremely conservative

Alternative 1 meets both of the threshold criteria discussed above as well as providing long term effectiveness and permanence through natural attenuation and degradation The toxicity mobility and volume of OU 1 groundwater COCs would be reduced through dispersion biological degradation, and volatilization In terms of short term effectiveness and implementability, this alternative is one of the most implementable alternatives proposed, which results in the lowest short term risks to workers the public and the environment If at any time during the monitoring period COC concentrations appear higher than predicted the french drain sumps would be pumped to the Building 891 water treatment plant to provide additional protection This alternative results in a very low total present worth cost because institutional controls are currently in place at the RFETS Monitoring would be continued under this alternative throughout the institutional control period

State and community acceptance of this alternative will be evaluated after comments are received on the CMS/FS report and the PRAP/PP At this time the results of this CMS/FS indicate that Alternative 1 Institutional Controls without the French Drain is the preferred remedial action alternative for OU 1 groundwater

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# LIST OF ACRONYMS

| | |
|---|---|
| ALARA | as low as reasonably achievable |
| ARAR | applicable or relevant and appropriate requirement |
| BRA | Baseline Risk Assessment |
| CAD/ROD | Corrective Action Decision/Record of Decision |
| CAMU | Corrective Action Management Unit |
| $CCl_4$ | carbon tetrachloride |
| CCR | Colorado Code of Regulations |
| CDPHE | Colorado Department of Public Health and the Environment |
| CERCLA | Comprehensive Environmental Response Compensation and Liability Act |
| CFR | Code of Federal Regulations |
| CMS/FS | Corrective Measures Study/Feasibility Study |
| COC | contaminant of concern |
| CWQCC | Colorado Water Quality Control Commission |
| DCE | dichloroethene |
| DNAPL | dense non aqueous phase liquid |
| DOE | U S Department of Energy |
| EDE | effective dose equivalent |
| EE | Environmental Evaluation |
| EPA | U S Environmental Protection Agency |
| GAC | granular activated carbon |
| GRAs | general response actions |
| IAG | Inter Agency Agreement |
| IHSSs | Individual Hazardous Substance Sites |
| IM/IRA | Interim Measure/Interim Remedial Action |
| LHSU | lower hydrostratigraphic unit |
| MCL | Maximum Contaminant Level |
| MCLG | Maximum Contaminant Level Goal |
| NCP | National Oil and Hazardous Substances Pollution Contingency Plan |
| NESHAP | National Emission Standards for Hazardous Air Pollutants |
| O&M | operation and maintenance |
| OSWER | Office of Solid Waste and Emergency Response |
| OU 1 | Operable Unit 1 |
| OU 2 | Operable Unit 2 |

| | |
|---|---|
| PAHs | polynuclear aromatic hydrocarbons |
| PAM | Proposed Action Memorandum |
| PCBs | polychlorinated biphenyls |
| PCE | perchloroethene (or tetrachloroethene) |
| PHE | Public Health Evaluation |
| PRAP/PP | Proposed Remedial Action Plan/Proposed Plan |
| PRG | preliminary remediation goal |
| RF | radio frequency |
| RAOs | remedial action objectives |
| RCRA | Resource Conservation and Recovery Act |
| RFEDS | Rocky Flats Environmental Database System |
| RFETS | Rocky Flats Environmental Technology Site |
| RFI/RI | RCRA Facility Investigation/Remedial Investigation |
| SDWA | Safe Drinking Water Act |
| SID | South Interceptor Ditch |
| SWMU | Solid Waste Management Unit |
| SVE | soil vapor extraction |
| SVOC | semivolatile organic compound |
| TBC | to-be-considered |
| TCA | trichloroethane |
| TCE | trichloroethene |
| TM | Technical Memorandum |
| TMV | toxicity mobility or volume |
| TSCA | Toxic Substances Control Act |
| UHSU | upper hydrostratigraphic unit |
| USC | United States Code |
| VOC | volatile organic compound |

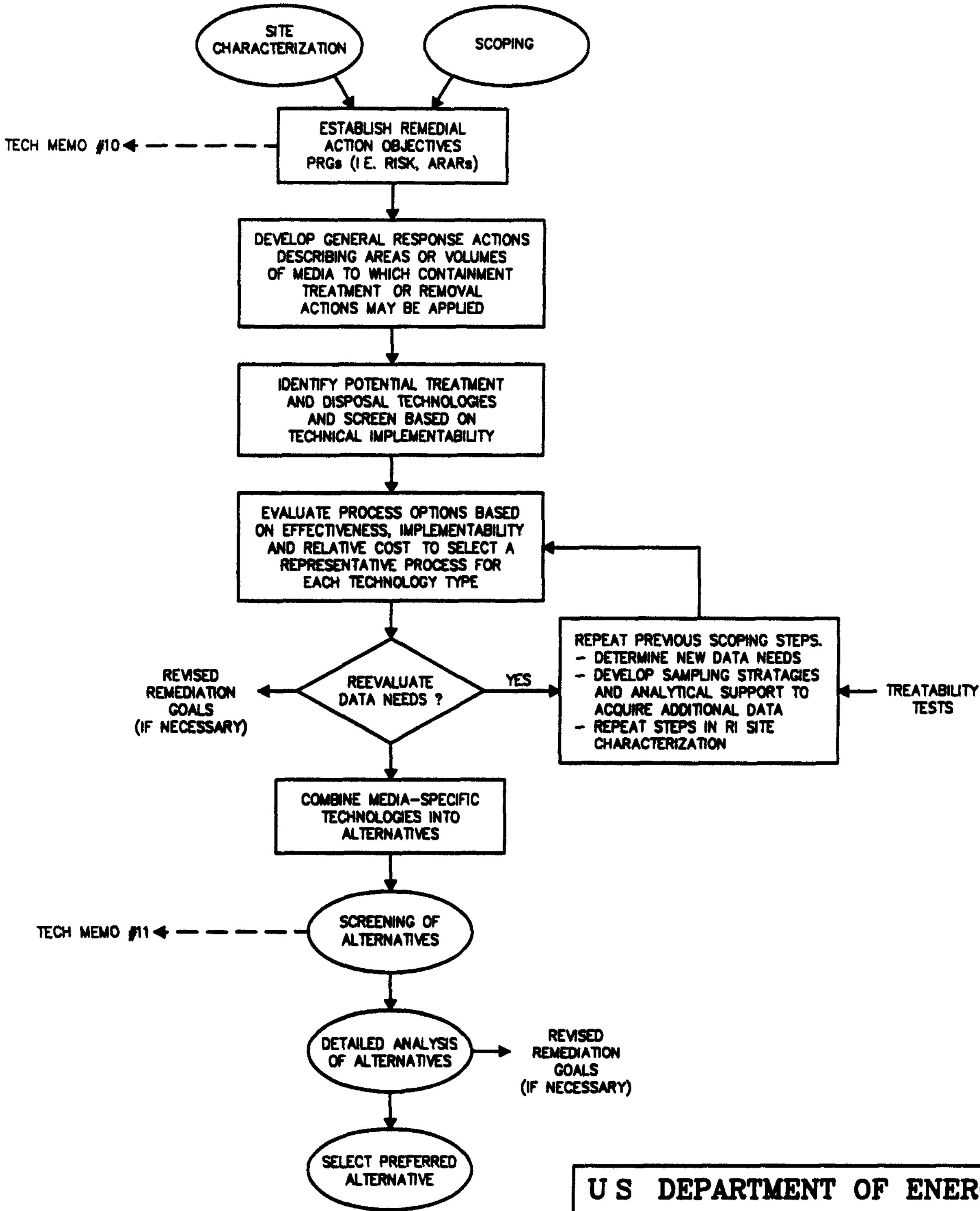
# Section 1

# 1 0 INTRODUCTION

This Corrective Measures Study/Feasibility Study (CMS/FS) report is part of a comprehensive program developed by the U S Department of Energy (DOE) the U S Environmental Protection Agency (EPA) and the Colorado Department of Public Health and the Environment (CDPHE) This program is authorized pursuant to the Rocky Flats Interagency Agreement (IAG) of January 1991 In accordance with the requirements of the IAG this CMS/FS report addresses provisions of both the Comprehensive Environmental Response Compensation and Liability Act (CERCLA), and the Resource Conservation and Recovery Act (RCRA) Background information on Operable Unit 1 (OU 1) of the Rocky Flats Environmental Technology Site (RFETS) was obtained primarily from the *Phase III RCRA Facility Investigation/Remedial Investigation (RFI/RI) Report* (DOE 1994a) However wherever appropriate more recent data were used to develop figures and contour maps presented herein These data were obtained directly from the Rocky Flats Environmental Database System (RFEDS) and were used to supplement the information presented in the Phase III RFI/RI report

## 1 1 Purpose and Organization of Report

This CMS/FS is based on the CERCLA RI/FS process developed by EPA for the Superfund program (EPA 1988a EPA 1990b) Essentially the process is designed to provide decision makers with a tool by which they can make an informed decision regarding the preferred remediation alternative for a suspected hazardous waste site The methodology that EPA has established for this type of study is outlined in the *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA 1988a) and is shown graphically in Figure 1 1 Pursuant to the IAG, two technical memorandums (TMs) were prepared to present the general approaches proposed for the CMS/FS to the regulatory agencies involved prior to submitting the draft CMS/FS report Technical Memorandum #10 *Development of Remedial Action Objectives* (DOE 1994b), and Technical Memorandum #11 *Development and Screening*

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**Golden Colorado**

**881 HILLSIDE AREA**
**OPERABLE UNIT NO 1**

**CMS/FS Logic Flow Diagram**

**Figure 1-1**

OU1-LFD DWG

for review and will not be finalized since they do not require formal approval Comments received on the documents are incorporated herein where appropriate

The method proposed by EPA can be viewed as occurring in three distinct phases These phases are (1) the development of alternatives (2) the screening of alternatives and (3) the detailed analysis of alternatives

The first phase of the CMS/FS involves determining which technologies will be used in the development of alternatives and then combining these technologies to form a range of remedial alternative options for the operable unit This determination is based on the following items and is documented in TM #10 and #11 results are incorporated in Section 2 0 of this report

- Development of media specific remedial action objectives (RAOs)
- Development of media specific general response actions (GRAs)
- Identification of volumes and/or areas of the media which require GRAs
- Identification and screening of technologies and process options for each GRA
- Evaluation of process options within each technology type to select a representative process option for the development of remedial action alternatives

The second phase of the CMS/FS is an optional step depending on the number of alternatives developed during the first phase If numerous waste management options were developed after the screening of technologies then these alternatives can be screened to reduce the number of alternatives that are carried forward for detailed analysis This screening is conducted on the basis of effectiveness implementability and cost and is documented in TM #11 Results of the screening are incorporated in Section 3 0 of this report

The final phase in the CMS/FS process is documented in Section 4 0 and consists of the detailed analysis of alternatives which were carried forward from the screening phase described above In this phase the alternatives are further refined and analyzed in detail with respect to nine cntena as required by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) The cntena are listed below

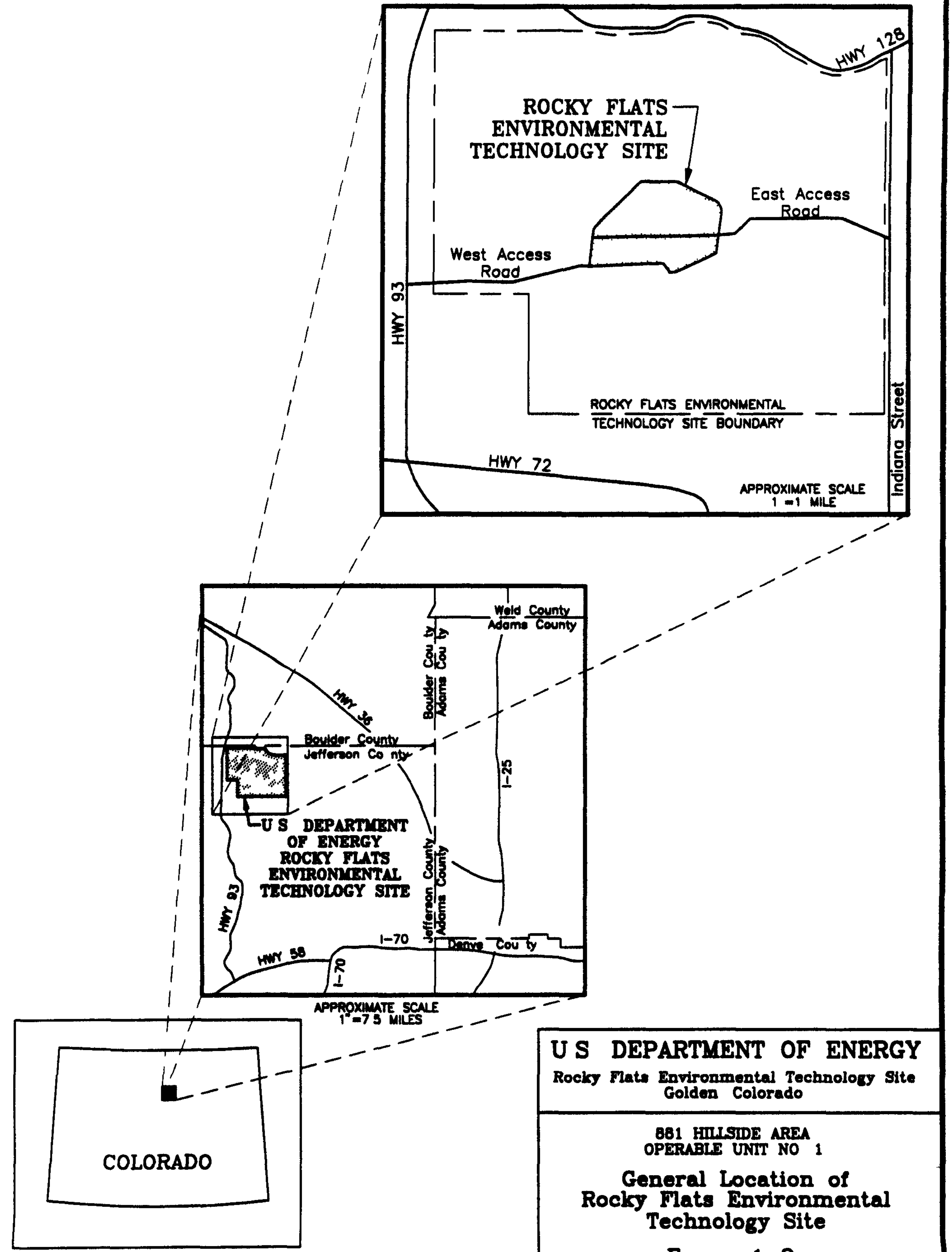
- Overall protection of human health and the environment
- Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)
- Long term effectiveness and permanence
- Reduction of toxicity mobility or volume
- Short term effectiveness
- Implementability
- Cost
- State acceptance
- Community acceptance

In the detailed analysis these cntena are evaluated in two ways First each alternative is evaluated individually on its ability to satisfy the nine cntena, and second the alternatives are subjected to a comparative analysis (against each other) to assess the relative performance of each alternative against the cntena

These chapters document the CMS/FS process as it was applied to OU 1 of the RFETS Sections 2 0 through 4 0 contain the technical basis for the selection of a preferred alternative while Section 1 0 presents the background for the report A site description and history along with a summary of the extent of contamination and the results of the baseline risk assessment are included in this section Several appendices are included to support the information presented in the CMS/FS

## 1 2 Background Information

The RFETS is a DOE owned facility and is located approximately 16 miles northwest of downtown Denver Colorado (see Figure 1 2) RFETS occupies approximately 6,550 acres of federally-owned land in northern Jefferson County Colorado The majority of the RFETS plant buildings are located within a 400-acre area referred to as the RFETS security area The 6 150

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OPERABLE UNIT NO 1

General Location of Rocky Flats Environmental Technology Site

Figure 1-2

OU1-LOC DWG

acres surroundıng the plant buıldıngs provıde a buffer zone around the RFETS securıty area RFETS ıs operated and managed by EG&G Rocky Flats Inc for DOE

In July 1994 the plant was renamed to the RFETS to better reflect ıts new mıssıon of envıronmental restoratıon and the advancement of new and ınnovatıve technologıes for waste management characterızatıon, and remedıatıon Untıl 1992 RFETS fabrıcated nuclear weapon components from plutonıum, uranıum beryllıum and staınless steel Parts made at the plant were shıpped elsewhere for assembly Support actıvıtıes ıncluded chemıcal recovery and purıficatıon of recyclable transuranıc radıonuclıdes and research and development ın metallurgy machınıng nondestructıve testıng coatıngs remote engıneerıng chemıstry and physıcs The productıon process at RFETS resulted ın the generatıon of radıoactıve and non radıoactıve wastes On sıte storage and dısposal of these wastes has contrıbuted to hazardous and radıoactıve contamınatıon ın soıls, surface water and groundwater

### 1 2 1 881 Hıllsıde Sıte Background and Descrıptıon

Prevıously Buıldıng 881 was used for enrıched uranıum operatıons and staınless steel manufacturıng The laboratorıes ın Buıldıng 881 also performed analyses of the materıals generated ın productıon The buıldıng ıs located south of the plant on a south facıng hıllsıde whıch then slopes down to Woman Creek Topographıcally the hıghest poınt near OU 1 ıs Buıldıng 881, approxımately 6 000 feet above mean sea level and the lowest poınt ıs ın Woman Creek about 5 830 feet above mean sea level Two surface draınages occur ın the vıcınıty of OU 1 Woman Creek flows along the base of 881 Hıllsıde south of OU-1 and the South Interceptor Dıtch (SID) crosses OU 1 between the plant and Woman Creek A french draın was constructed ın 1993 across a sıgnıficant portıon of OU 1 above the SID to collect alluvıal groundwater as an Interım Measure/Interım Remedıal Actıon (IM/IRA)

OU 1 ıncludes 11 unıts prevıously ıdentıfied as Indıvıdual Hazardous Substance Sıtes (IHSSs) where past operatıonal practıces have resulted ın the contamınatıon of soıls surface water, and/or groundwater Of the 11 IHSSs, two have been ıdentıfied as havıng potentıally the most contamination These two areas are identified as IHSSs 119 1 and 119 2 and are referred to as Multiple Solvent Spill Sites The areas are located east of Building 881 and along the southern perimeter road Beginning in 1967 these two areas were used as drum storage areas The drums contained unknown types and quantities of solvents and solvent wastes and possibly some radionuclides Drum storage operations were suspended at IHSSs 119 1 and 119 2 in 1972 OU 1 includes nine additional IHSSs (see identification numbers in Figure 1 3) Brief descriptions of all OU 1 IHSSs are included in Table 1 1

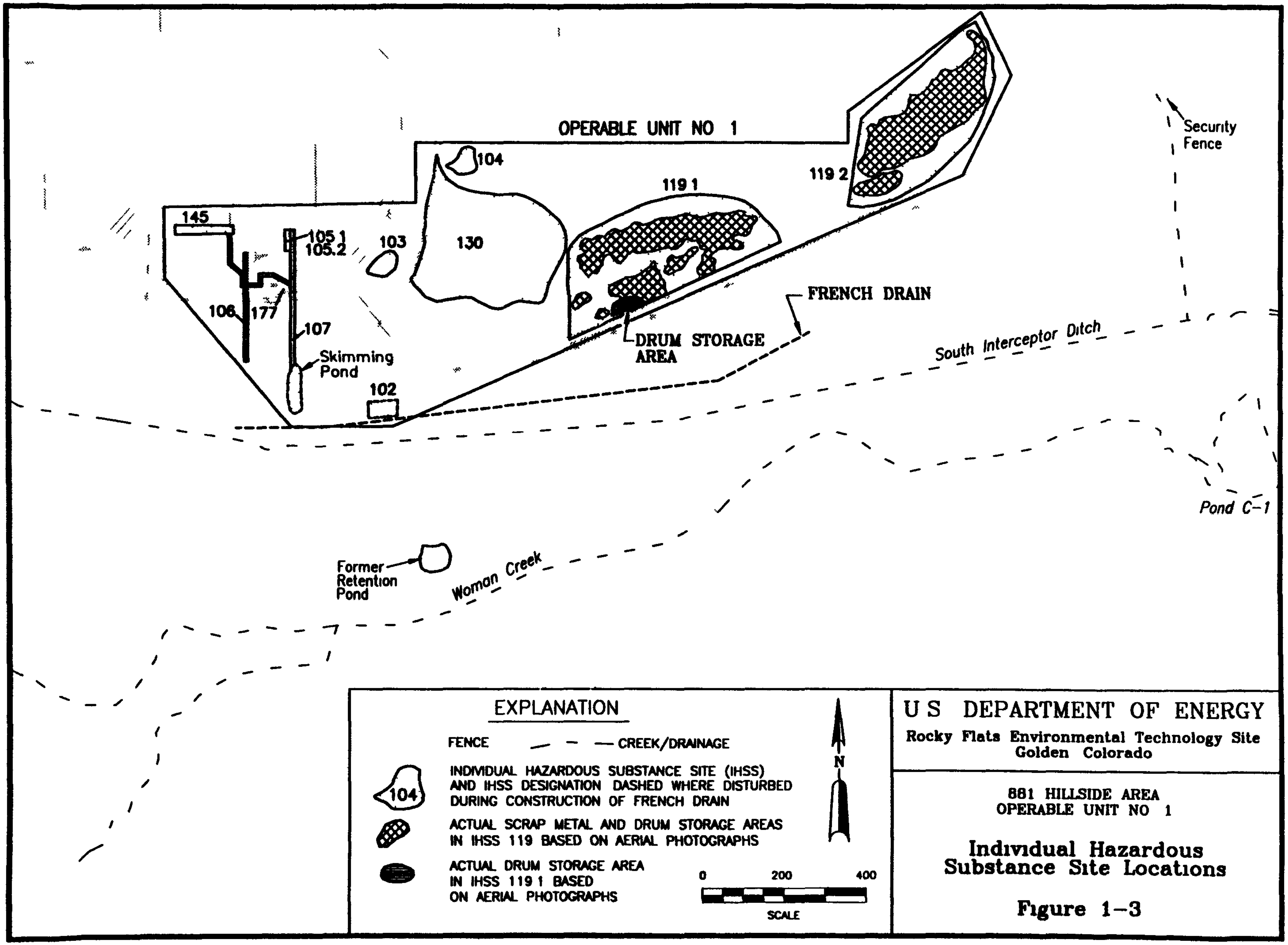
### 1 2 2 Geomorphology

The geomorphology of a site can influence potential contaminant transport pathways including surface water and groundwater flow The geomorphology at OU 1 reflects the interaction of several erosional and depositional processes on the bedrock and surficial materials underlying the site and accounts for the gently rolling to moderately steep slopes developed on 881 Hillside Subsequent to the initial siting of the plant the terrain has been recontoured in several areas at various times These include the construction of Building 881 the placement of fill and waste materials in several areas including the contractor yard and several IHSSs the grading of roads at the site the construction of the SID and most recently, the construction of the french drain

The steepness of the hillside combined with various construction and excavation activities at OU 1 has resulted in mechanical failure manifested in widespread slumping of material The number of damaged wells on the hillside testifies to the prevalence of earth movement Previous studies have also delineated slumps in the 881 Hillside area One study map shows the entire hillside as being susceptible to landslides (DOE 1994a)

### 1 2 3 Hydrogeology

Groundwater hydrogeology has been a central component of three phases of study at OU 1 The most recent interpretations in the Phase III RFI/RI report represent a comprehensive evaluation

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**Individual Hazardous Substance Site Locations**

**Figure 1-3**

OU1-IHSS DWG

## Table 1 1
## Individual Hazardous Substance Site Descriptions

| IHSS Number | IHSS Name | Description |
|---|---|---|
| 102 | Oil Sludge Pit Site | Approximately 40 x 70 $ft^2$ area located approximately 180 feet south of Building 881 where 30 to 50 drums of non-radioactive oily sludge were emptied in the late 1950s The sludge was from the cleaning of two No 6 fuel oil tanks designated as IHSSs 105 1 and 105 2 and was backfilled when disposal operations ceased |
| 103 | Chemical Burial Site | Approximately 50 feet in diameter (2,000 $ft.^2$) the pit is circular is shape and is located approximately 150 feet southeast of Building 881 on 1963 aerial photographs Area was reportedly used to bury unknown chemicals |
| 104 | Liquid Dumping Site | Reportedly a former (pre-1969) liquid waste disposal pond in area east of Building 881 no exact location or dimensions of pit location is uncertain due to poor quality of 1965 aerial photograph Approximate dimensions are 50 x 50 $ft^2$ |
| 105 1 105 2 | Out-of-Service Fuel Oil Tank Sites | Located immediately south of Building 881 these were storage tanks for No 6 fuel oil Suspected leaks in 1972 Tanks closed in place through filling with asbestos-containing material and cement. IHSS 107 the Hillside Oil Leak Site may have been caused by leakage from these tanks |
| 106 | Outfall Site | Overflow line from the sanitary sewer sump in Building 887 The outfall was used for discharge of untreated sanitary wastes in the 1950s and 1960s Due to concern about discharges from the outfall entering Woman Creek, several small retention ponds and an interceptor ditch were built in 1955 and 1979 respectively to divert the outfall water to Pond C 2 |
| 107 | Hillside Oil Leak Site | Site of 1972 fuel oil spill from Building 881 foundation drain outfall A concrete skimming pond was built below the foundation drain outfall to contain the oil flowing from the foundation drain, and an interceptor ditch was constructed to prevent oil contaminated water from reaching Woman Creek |
| 119 1 119 2 | Multiple Solvent Spill Sites | Former drum storage areas east of Building 881 along the southern perimeter road IHSS 119 1 is the larger western drum and scrap metal storage area and appears to have contained mostly drums in the southern part of the IHSS and mostly scrap metal in the northern part, although material was moved around frequently as documented by aerial photographs IHSS 119 2 is the smaller eastern drum and scrap metal storage area and appears to have contained mostly scrap metal The drums contained unknown quantities and types of solvents and wastes The scrap metal may have been coated with residual oils and/or hydraulic coolants |
| 130 | Radioactive Site 800 Area #1 | Area east of Building 881 Used between 1969 and 1972 to dispose of soil and asphalt contaminated with low levels of plutonium and uranium IHSS 130 is referred to as the Contaminated Soil Disposal Area East of Building 881 in the HRR to better match the history of waste disposal the site is included in the discussion of the 900 area at RFETS in that report IHSS 130 contains approximately 320 tons or 250 cubic yards which came from three sources 1) plutonium-contaminated soil and asphalt placed in September of 1969 2) road asphalt and soil rad contaminated by leaking drum in transit and 3) 60 cu yds of plutonium-contaminated soil removed from around the Building 774 process waste tanks in 1972 |
| 145 | Sanitary Waste Line Leak | Six inch cast iron sanitary sewer line that originates at the Building 887 lift station and that leaked on the hillside south of Building 881 The line had conveyed sanitary wastes and low-level radioactive laundry effluent to the sanitary treatment plant from about 1969 to 1973 |

of the OU hydrogeology based on eight years of investigation and monitoring Groundwater at OU 1 is present in the unconsolidated surficial material consisting of the Rocky Flats Alluvium colluvial material and the Valley Fill Alluvium Groundwater is also inferred to occur locally in the upper portion (i e 0 to 25 feet) of the Laramie claystone bedrock These units contain unconfined groundwater and comprise the upper hydrostratigraphic unit (UHSU) Groundwater also occurs in deeper (>25 feet) bedrock sandstones and claystones of the upper Laramie Formation This bedrock unit is labeled the lower hydrostratigraphic unit (LHSU) and groundwater here is confined in places The Phase III RFI/RI results for OU 1 indicate the presence of these units, based on their exhibiting different hydrogeological characteristics although defining the boundary is difficult

Over most of the site, UHSU groundwater flow occurs in disconnected northwest southeast trending channels that have been scoured into the bedrock surface Bedrock highs and lithologic variability, notably the presence of clay lenses, act to retard the rate of groundwater flow Flow has been observed in glide planes bounding the slump blocks Parts of OU 1 particularly in the eastern portion are only seasonally wet and contain groundwater only in the spring months when there is high precipitation Groundwater levels across OU 1 are higher in spring than in the remainder of the year

Recharge to the UHSU is minimal and is primarily through infiltration of precipitation, which ranges from 2 inches per hour for initial infiltration to 0 5 inches per hour for final (saturated) infiltration Localized sources of recharge include seepage from the Rocky Flats Alluvium to colluvial materials and former recharge from the Building 881 footing drain which has since been rerouted to the french drain collection system Flow from this drain averages 3 5 gallons per minute (gpm) Discharge occurs largely through evapotranspiration and discharge at boundaries such as seeps, Woman Creek the South Interceptor Ditch (SID) and the french drain (DOE 1994a)

From aquifer test data the average linear flow velocity was estimated at 70 feet per year in the vicinity of IHSS 119 1 8 feet per year in the vicinity of Building 881, and 180 feet per year within the Valley Fill Alluvium The volume of UHSU groundwater at OU 1 was estimated at 5 8 acre feet in January 1992 to 5 acre feet in April 1992 (DOE 1994a)

Measured hydraulic conductivities vary widely because geological characteristics that control permeabilities vary widely in the materials that comprise the unconsolidated material of the UHSU The overall range of hydraulic conductivity values estimated for UHSU materials was 3 x $10^{-3}$ to 2 x $10^{-6}$ cm/sec The hydrologic data show that a wide range of hydraulic conductivity values characterize the surficial materials at OU 1 Also the horizontal hydraulic conductivity values in bedrock appear to be 10 to 1 000 times greater than values in the vertical direction which range from 1 2 x $10^{-3}$ to 2 5 x $10^{-9}$ Water levels screened in the UHSU rise annually in response to spring recharge and decline during the remainder of the year (DOE 1994a)

Based on groundwater level data from the french drain monitoring wells the recently installed french drain system appears to be effective in capturing UHSU groundwater and aqueous phase contaminants migrating from OU 1 Data from April 1993 a month of high precipitation showed that most of the UHSU monitoring wells were dry (DOE 1994a)

## 1 3 Nature and Extent of Contamination

This section summarizes the results of the nature and extent of contamination at OU 1 as presented in the Phase III RFI/RI report This information is presented by contaminant group with specific areas identified as impacted Table 1 2 summarizes the contaminants originally identified in the Phase III RFI/RI report for the media of groundwater surface soils subsurface soils surface water, and sediments

## Table 1 2
## Contaminants Identified in the RFI/RI by Media

| Contaminant | Ground Water | Surface Soil | Subsurface Soil[a] | Surface Water[a] | Sediment[a] |
|---|---|---|---|---|---|
| **Volatile Organic Compounds** | | | | | |
| Carbon Tetrachloride | X | | X | | |
| Chloroform | X | | X | | |
| 1 1 Dichloroethane | X | | | X | |
| 1 2 Dichloroethane | X | | X | X | |
| 1 1 Dichloroethene | X | | X | X | |
| 1 2 Dichloroethene | X | | | X | |
| cis 1 2 Dichloroethene | X | | | | |
| Tetrachloroethene | X | | X | X | |
| Toluene | X | | X | X | X |
| Total Xylenes | X | | X | X | |
| 1 1 1 Trichloroethane | X | | X | X | X |
| 1 1 2 Trichloroethane | X | | | | |
| Trichloroethene | X | | X | X | |
| **Metals** | | | | | |
| Selenium | X | | | | |
| Vanadium | X | | | | |
| **Radionuclides** | | | | | |
| Americium | | X | X | X | X |
| Uranium | | X | X | | |
| Plutonium | | X | X | X | X |
| **Polychlorinated Biphenyls (PCBs)** | | | | | |
| AROCLOR 1248 | | X | | | |
| AROCLOR 1254 | | X | | | X |

## Table 1-2
## (Continued)

| Contaminant | Ground Water | Surface Soil | Subsurface Soil[a] | Surface Water[a] | Sediment[a] |
|---|---|---|---|---|---|
| **Polynuclear Aromatic Hydrocarbons (PAHs)** | | | | | |
| Acenaphthene | | X | X | | |
| Acenaphthylene | | X | | | |
| Anthracene | | X | X | | |
| Benzo(a)anthracene | | X | X | | |
| Benzo(a)pyrene | | X | X | | |
| Benzo(b)fluoranthene | | X | X | | X |
| Benzo(ghi)perylene | | X | X | | |
| Benzo(k)fluoranthene | | X | X | | X |
| Chrysene | | X | X | | X |
| Dibenzo(a h)anthracene | | X | | | |
| Fluoranthene | | X | X | | X |
| Fluorene | | X | X | | |
| Indeno(1 2 3-cd)pyrene | | X | X | | |
| 2 Methylnaphthalene | | | X | | |
| Naphthalene | | X | X | | |
| Phenanthrene | | X | X | | X |
| Pyrene | | X | X | | X |

X Contaminant is a COC which has been detected in the medium

a Contaminants in shaded media did not result in a cancer risk greater than $10^{-6}$ nor a hazard index greater than one

### 1 3 1 Volatile Organic Compounds

Volatile organic compounds (VOCs) are present in subsurface soils and occur in some locations at high concentrations in groundwater (> 1 0 mg/ℓ) Chlorinated solvents occur sporadically and at low concentrations (< 1 0 mg/kg) in subsurface soils throughout the IHSSs Sources for the high concentrations of these VOCs in groundwater have not been sampled but there is adequate circumstantial evidence to conclude that subsurface soils with high chlorinated solvent concentrations (sources) exist Toluene occurs throughout OU 1 in subsurface soils at relatively low concentrations however the source of the toluene is unknown The occurrence of toluene in the OU 1 samples may be a result of laboratory or field introduced contamination

Three general source areas for VOCs in groundwater at OU 1 have been identified (see Figure 1-4) Within these three general areas multiple release points appear likely based on concentration gradients and chemical fingerprints The three general source areas include

- South of Building 881
- IHSS 119 1 area
- Southeast of IHSS 119 2

These areas are discussed further in the following paragraphs For the sake of consistency the terms used to define these areas are used throughout the report The terms are used in place of IHSS designations because for the most part actual sources have not been conclusively determined for all of these contaminated groundwater areas In addition remediation measures would need to be evaluated for the "plumes directly and could not be limited to individual IHSSs

Area South of Building 881

Groundwater in this area contains generally low concentrations of chlorinated solvents ranging from non-detects to 130 μg/ℓ as a maximum However, the spatial distribution of the detections is inconsistent and does not clearly indicate a discrete source In addition the description of the historical activities at IHSSs 145 107, and 106 does not clearly indicate use or disposal of chlorinated compounds

The maximum detection of 130 $\mu g/\ell$ of 1 1 1 trichloroethane (1 1 1 TCA) in samples collected from well 1 87 may indicate IHSS 145 is a source However the results of a soil gas survey presented in the previous Phase I RI Report revealed no 1 1 1 TCA in the soil gas sample collected closest to well 1 87 and thus do not corroborate the source

Soil gas survey results reveal a high concentration of tetrachloroethene (PCE) in soil gas approximately 30 feet southwest of well 5287 and is shown on Figure 1-4 as a suspected source area This detection is the second highest out of several hundred soil gas samples collected at OU 1 suggesting a source for PCE in subsurface soils and the possible existence of residual dense non aqueous phase liquid (DNAPL) (DOE 1994a) The lack of PCE detections in groundwater samples collected from wells south of the soil gas detection (well 5487/5387) suggest that either the solvent release did not reach the water table (as a free phase wetting front) or that groundwater is not present at the location of the release

IHSS 119.1 Area

Documented waste storage practices at this IHSS resulted in the release of chlorinated solvents which now pose a continuing source for VOCs in groundwater VOC concentrations are highest in the southwest portion of the IHSS This fact coupled with the apparent presence of drummed waste as seen in historical aerial photographs permits approximate definition of the source area in the southwest portion of the IHSS Within this source area, individual releases from drums cannot be resolved due to their apparent small areal extent However the results of the Phase I soil gas survey suggest several locations which may represent the actual release points thus permitting an estimation of where DNAPL contaminants may have originated A comparison of the chemical suite detected in groundwater at several locations within the drum storage area revealed at least two distinct chemical mixtures One is dominated by trichloroethene (TCE) and

1 1 1 TCA (well 0974) and the other is dominated by carbon tetrachloride ($CCl_4$) (well 1074) which supports the multiple release point concept

Given the assumed release mechanism namely leaking drums on the ground surface it is reasonable to assume that gravity driven wetting fronts of chlorinated solvents may have advanced through the vadose zone and at least portions of the saturated zone If consistent with solvent migration theories as the wetting front passed it may have left behind residual free phase chlorinated solvents in both the vadose and saturated zone This residual would thus constitute a continuing source for VOCs in groundwater at this location

A major finding of the Phase III RFI/RI was that chlorinated solvents released at IHSS 119 1 have likely entered the UHSU as DNAPLs Phase III RFI/RI results suggest that the DNAPL zone is limited to the UHSU directly beneath IHSS 119 1 An aqueous plume of TCE, TCA, and several other VOCs has been defined as emanating from the DNAPL zone and has migrated along the preferential groundwater flow pathway This plume is currently being intercepted by the french drain

The migration of VOC contamination in groundwater downgradient of the western portion of IHSS 119 1 is currently limited by the french drain which acts as a hydraulic barrier in the UHSU The historical maximum concentration of VOCs in groundwater is defined by well 4787 although in general well 4787 has had sporadic low level detections of VOC contaminants

The extent of contamination originating from the unidentified source is unknown Well 0687 was destroyed during the construction of the french drain The french drain now captures all UHSU groundwater that once flowed through the area occupied by well 0687

Area Southeast of IHSS 119.2

Concentrations of chlorinated solvents detected in two closely spaced monitoring wells downgradient of IHSS 119 2 (wells 6286 and 6386) are attributed to potential VOC release areas at both IHSS 119 2 and outside the operable unit The occurrences of these VOCs in groundwater within the IHSS include one time detections of 9 3 $\mu g/\ell$ in UHSU well 34791 and 0 1 $\mu g/\ell$ LHSU well 4587 Chloroform detections occurred three times in well 4587 with a maximum detection of 18 $\mu g/\ell$

Wells 6286 and 6386 contain contaminated groundwater and are located in a drainage hydraulically downgradient from IHSS 119 2 Therefore a VOC release point is suspected and is shown on Figure 1-4 based on the location of suspected waste disposal features depicted on aerial photographs The location and size of this suspected VOC release point is uncertain It is possible that contamination from the 903 Pad is also responsible for the VOCs detected in monitoring wells on the Hillside The 903 Pad is upgradient of the impacted wells and is known to be a source for $CCL_4$ and other dissolved chlorinated solvents in groundwater

The occurrence of chlorinated solvents in subsurface soils is limited to a maximum detection of 140 $\mu g/kg$ in one borehole (BH5887) The occurrence of VOCs in soil gas is limited to low levels of PCE and 1 1,1 TCA at one location within the IHSS However the magnitude of the soil gas detections is several orders of magnitude less than those noted at Building 881 and IHSS 119 1 and are more representative of the local background around IHSS 119 2 Nevertheless as was the case at IHSS 119 1 the presence of a VOC release point within IHSS 119 2 boundaries is suspected based on the downgradient groundwater chemistry

1 3 2 <u>Metals</u>

Metal contaminants include vanadium and selenium, both of which are significantly elevated in groundwater These elements are not elevated in surface or subsurface soils Although these substances were not reported to have been associated with wastes stored or disposed of at OU 1 they appear to be elevated primarily in areas where VOC wastes were stored at OU 1 It is postulated that these metals are undocumented constituents of wastes stored at IHSS 119 1 It is unlikely that they were leached from the soil by organic wastes disposed of at OU 1 since hydraulic oil and chlorinated solvents have poor chelation properties and are not strongly acidic or basic Nevertheless the potential for leaching of these metals exists Alternatively these constituents may be naturally occurring however there is insufficient data to support either conclusion Four areas have been identified at OU 1 with elevated selenium and/or vanadium as discussed below

IHSS 119.1 Area

Multiple detections of selenium and vanadium were noted in monitoring wells located in the southwestern portion of the IHSS (Figure 1 5) Typically the elevated metals were seen in association with VOCs In particular, the highest metal concentration (2200 $\mu g/\ell$ of Se) was detected in a well with one of the highest VOC concentrations anywhere at OU 1 (Well 1074) The maximum downgradient extent of selenium in groundwater at IHSS 119 1 appears to be in the vicinity of well 0487 The occurrence of vanadium is similar to selenium except that vanadium only occurs above background in UHSU wells

Area South of Building 881

One detection of vanadium was noted at well 5387 at approximately six times the background level of 30 mg/$\ell$ This well exhibits concentrations of various chlorinated compounds in the 1 to 25 $\mu g/\ell$ range Several potential VOC source areas have been identified in the area south of Building 881, however well 5387 is not particularly close to the suspected source areas Nevertheless it is conceivable that the vanadium present in groundwater at 5387 represents a plume originating from one of the VOC source areas previously discussed The extent of vanadium concentrations above background near Building 881 appears to be limited to the immediate vicinity around well 5387

Area East of IHSS 102

One detection of vanadium and three detections of selenium were noted above the background level in well 6986 No detections of VOCs have been noted at this well It is unclear whether these detections represent contamination or naturally occurring levels as the maximum vanadium and selenium concentrations represent 126 percent and 194 percent of background respectively Based on these relatively low levels a contaminant source is not suspected in this area

Southeast Corner of IHSS 130

Vanadium is the only contaminant detected at this location over background levels A maximum of 403 $\mu g/\ell$ was detected at well 37191 which represents approximately five times the background level Only exceedingly low levels of VOC contamination ($<0\ 5\ \mu g/\ell$) was found in association with the vanadium The extent of vanadium and selenium contamination in the southeast corner of IHSS 130 appears to be limited to the immediate vicinity around well 37191

1 3 3 Semivolatile Organic Compounds

The only semivolatile organic compounds (SVOCs) that are identified contaminants at OU 1 are PAHs and PCBs Although PAHs are considered to be OU 1 contaminants in the Phase III RFI/RI they are not considered to be of OU 1 origin PAHs occur over most of OU 1 in surface soils and tend to decrease in concentration with depth PAHs have also been detected in sediments Several areas of OU 1 have been identified where PAHs appear more concentrated relative to the surrounding area The areas do not coincide with IHSS locations (see Figure 1 6) The sources for the PAHs at OU 1 are presumed to be general urban fallout including asphalt dust and larger particles vehicle exhaust and furnace exhaust

1 3 4 Polychlorinated Biphenyls

PCB occurrence is restricted to IHSS 119 1 and 119 2 surface and subsurface soils (Figure 1 7) One PCB detection has been also noted in sediments However sediments are not addressed as part of the OU 1 CMS/FS and in addition this detection was at the western OU 1 boundary and is not considered of OU 1 origin The contaminant release mechanism for PCBs is unknown

1 3 5 Radionuclides

Americium plutonium, and uranium have been identified as OU 1 contaminants and are elevated in surface and subsurface soil In addition plutonium and americium are evaluated in surface water and sediment The widespread plutonium and americium contamination appears to be a result of deposition of wind-disseminated plutonium/americium-contaminated dust originating from the 903 Pad Area A general decrease in activities is noted from east to west ranging from a maximum of 22 7 pCi/g to 0 0076 pCi/g of plutonium and 4 15 pCi/g to 0 0129 pCi/g of americium (see Figure 1 8)

In contrast to the wide-spread plutonium/americium contamination, localized hotspots are present at OU 1 that are markedly contaminated with either plutonium/americium or uranium These "hotspots" are postulated to have arisen from releases of radionuclide-contaminated liquids stored in drums at OU 1 and are being addressed through an early removal action discussed later

Unlike plutonium and americium, uranium contamination is not wide-spread, although it is significantly elevated at discrete locations in surface and subsurface soils at OU-1 Uranium was below background levels at SS100393, slightly above background at SS100493 and significantly above background at SS100193 and SS100293 The low levels at SS100493 coupled with uranium 233 234/uranium 238 ratios of approximately 1 to 2 suggest the uranium may be naturally occurring The highest activities of uranium at SS100193 and SS100293 occur just beneath the surface as the deeper composites have the higher activities The maximum total uranium activity at SS100193 is approximately 550 pCi/g with a uranium 233 234/uranium 238 activity ratio of 3 5 This suggests contamination with enriched uranium The maximum total uranium activity at SS100293 is approximately 240 pCi/g with an activity ratio as high as 160 This suggests contamination with uranium-233 as the activity ratio far exceeds that for enriched uranium

## 1 4 Fate and Transport of Contaminants

This section discusses potential mechanisms by which contaminants identified in the Phase III RFI/RI can migrate Although several mechanisms are identified in the following sections, the groundwater medium is the most significant pathway Figure 1 9 depicts potential groundwater migration pathways Note that this figure does not include the volume of groundwater available for transport Many areas of OU 1 are currently dry and remain dry throughout the year The migration pathways presented in the figure merely present potential pathways assuming adequate groundwater is present

### 1 4 1 Volatile Organic Compounds

The release mechanisms for VOCs at OU 1 are varied including pure product leakage from stored drums possible leakage of dilute aqueous solutions of VOCs from pipelines and seepage of aqueous VOC solutions or pure product from impoundments and disposal pits In the area south of Building 881 the release mechanisms likely to have occurred include leaking pipelines and leakage from impoundments and disposal pits In the western portion of OU 1 (IHSS 119 1) the release mechanism is most likely leakage from drums stored on the land surface

Once the contaminant has entered the subsurface the pathways for VOC migration include gravity driven wetting fronts of aqueous solutions and/or small volumes of pure product through the vadose zone to the water table In the case of pure product, the density of the pure chlorinated solvent would allow the contaminant to migrate vertically through the saturated zone The migration as pure product would be arrested once the wetting front of contamination became depleted by the process in which residual product is retained by soils and rock Alternatively the migration would stop once the pure product came to rest in a topographic low on an impermeable surface (possibly the Laramie claystone) At this point, migration would continue in the form of an aqueous phase hydrocarbon plume (if groundwater is present) Precipitation and infiltration would also contribute to VOC migration as pure chlorinated solvents are dissolved and transported downward by infiltrating snowmelt and rainwater

The dissolved phase plume would migrate with the groundwater being retarded to varying degrees as a function of the physical and chemical properties of the contaminant geologic materials and groundwater In the case of OU 1 the organic contaminants identified in the Phase III RFI/RI report are primarily retarded by the clayey materials in the subsurface environment This is due to the relatively low organic carbon content of the soils found in OU 1 Retardation is particularly significant for OU 1 contaminants with high $K_{ow}$ values like $CCL_4$ (DOE 1994a)

At OU 1 the shallow groundwater, which carries most of the contamination is controlled to a large degree by the topography of the bedrock surface Active channels in the bedrock are covered by unconsolidated material of varying thickness that is variably saturated Typically groundwater will flow towards the axis of the bedrock channel and continue downgradient along the axis of the channel potentially to the Woman Creek Alluvium Therefore at OU 1 an aqueous phase hydrocarbon plume in groundwater has the potential to discharge to Woman Creek although this is not likely due to the low initial volume of contaminants of concern (COCs) available for transport However the existing french drain acts as a hydraulic barrier preventing the discharge of contaminated groundwater in the western and central portions of OU 1 to Woman Creek In the eastern portion of OU 1 the potential exists for continuous contaminant migration pathways in groundwater from the suspect source areas to Woman Creek However conclusive evidence of this occurrence has not been found, and the COC concentrations found to date limit the amount of contamination available for transport

VOC-contaminated groundwater may also discharge to surface water through seeps which have historically been observed at OU 1 (DOE 1994a) While VOCs in surface water have been previously detected in the SID the recent construction of the french drain has intercepted this pathway

Other migration pathways for VOCs include volatilization of pure product into soil gas and subsequent migration of soil gas laterally and vertically away from the source area VOCs can also partition out of contaminated groundwater into soil gas or desorb from organic matter into the soil gas

VOCs would not be expected to migrate in significant quantities through surface water or wind transport of VOC contaminated surface soil This is based on the assumption that VOCs would quickly volatilize from the respective media One apparent exception to this is the occurrence of toluene in OU 1 surface soils Although there is no evidence to suggest that toluene is migrating through surface water or wind it apparently is persistent in near surface soils despite its relative high volatility

## 1 4 2 Metals

The mechanism for the release of metal contaminants into the environment is less clear than for VOCs It is presumed that selenium and vanadium are undocumented RFETS wastes that were associated with the VOC wastes stored and disposed of at OU 1 It is unlikely that they were leached from the soil by organic wastes disposed of at OU 1 since hydraulic oil and chlorinated solvents have poor chelation properties and are not strongly acidic or basic Nevertheless the potential for leaching of these metals exists Alternatively these constituents may be naturally occurring however there is insufficient data to support either conclusion In either case the primary migration pathway is as a dissolved phase contaminant plume in groundwater This migration pathway was previously presented for VOCs

## 1 4 3 Semivolatile Organic Compounds

It is presumed that PAHs were deposited at OU 1 as fallout of combustion products or wind blown asphalt dust Asphalt dust and larger particles may also have been transported and deposited by vehicles traversing OU 1 or by disposal of asphalt waste at OU 1

Once in place the dispersion mechanisms include vertical migration by infiltrating surface water carrying small particles composed of PAHs The low solubility and high $k_{oc}$ values of PAHs precludes mobilization of significant quantities in the dissolved form therefore transport via groundwater is not significant Other transport mechanisms include surface water and wind transport of particulate

### 1 4 4 Polychlorinated Biphenyls

Transport mechanisms relevant for PCBs are similar to those for PAHs however the source areas for PCBs are more discrete than for PAHs PCBs are expected to be very immobile given the high $k_{oc}$ values and the high carbon and clay content in surface soils at OU 1 Adsorption of PCBs at OU 1 is expected to be substantial on soils and clay particles (DOE 1994a)

### 1 4 5 Radionuclides

Transport mechanisms relevant to radionuclides are similar to PAHs In particular plutonium has a strong affinity for the solid phase and will not be readily mobilized by precipitation and infiltration Plutonium is strongly adsorbed to clay particles and is expected to undergo strong cation-exchange reactions due to its strong positive charge (DOE 1994a) The primary transport mechanism for plutonium is wind dispersion

## 1 5 Baseline Risk Assessment

The OU 1 Baseline Risk Assessment (BRA) consists of both a public health evaluation and an environmental evaluation The primary purpose of each evaluation is to examine the current and future risks associated with contaminants identified during the analysis of the nature and extent of contamination The following subsections summarize each evaluation and provide an overall summary of the risks associated with OU 1

## 1 5 1 Public Health Evaluation

During the course of the Public Health Evaluation (PHE) site population and land use data were analyzed in order to devise several representative exposure scenarios (potentially exposed receptors) for assessing the risk to current and future human health from identified contaminants at the 881 Hillside Area For each of these scenarios pathways were traced which represented exposure routes from the source to potential receptors

Pathway elements were examined relative to the results of the Phase III field investigation which indicated that contamination exists in groundwater surface soils subsurface soils, sediments and surface waters The contaminants identified in these areas included VOCs PAHs PCBs inorganic contaminants and radionuclides The contaminant release mechanisms evaluated were leaching volatilization resuspension of particulates by wind etc Potential transport media identified were surface water groundwater, air soil and biota The exposure route (the route of entry into the human body) for these media included ingestion inhalation, and dermal contact In accordance with the *Risk Assessment Guidance for Superfund Volume I Human Health Evaluation Manual (Part A)* (EPA 1989a) if any of the above-mentioned pathway elements is missing the projected receptor will not receive a chemical or radionuclide dosage and no excess risk will exist from that contaminant

The OU 1 physical environment including the french drain and treatment system was used with information about the potentially exposed population land use scenarios and exposure pathways to form the conceptual site model This was evaluated to identify complete pathways for credible and plausible exposure scenarios The following describes the specific land use scenarios and pathways selected with the conceptual site model for quantitative assessment

- Current Off Site Resident
  - — Inhalation of airborne particulates
  - — Soil ingestion (following deposition of particulates on residential soil)

— Dermal contact with soil (following airborne deposition of particulates)
— Ingestion of homegrown vegetables/fruit (following surface disposition and uptake of particulates)

- Current On Site Worker

— Inhalation of airborne particulates
— Soil ingestion
— Dermal contact with soil
— Sediment ingestion
— Dermal contact with sediment
— Surface water ingestion
— Dermal contact with surface water

- Future On Site Worker

— Inhalation of VOCs in endower air (office worker only) and outdoor air (construction worker only)
— Inhalation of airborne particulates
— Soil ingestion
— Dermal contact with soil
— Sediment ingestion (office worker only)
— Dermal contact with sediment (office worker only)
— Surface water ingestion (office worker only)
— Dermal contact with surface water (office worker only)

- Future On Site Ecological Researcher

— Inhalation of airborne particulates
— Soil ingestion
— Dermal contact with soil
— Sediment ingestion
— Dermal contact with sediment
— Surface water ingestion
— Dermal contact with surface water

- Future On-Site Resident

— Inhalation of indoor VOCs from basement vapor
— Inhalation of particulates
— Soil ingestion
— Dermal contact with soil
— Sediment ingestion
— Dermal contact with sediment
— Surface water ingestion

- Dermal contact with surface water
- Ingestion of homegrown vegetables/fruit (following surface deposition of particulates and uptake)

In addition four special cases of the on site residential scenarios were included to show the impact of the use of groundwater and to evaluate risk at the source It should be noted that groundwater yield was examined through several UHSU well simulations as part of the BRA These simulations indicated that the yield of contaminated groundwater in IHSS 119 1 is inadequate to support a household of four people (see Appendix F)

The results of the BRA indicate that only the media of groundwater and surface soils present a risk greater than the acceptable risk range of $10^{-4}$ to $10^{-6}$ The risk to a human receptor from exposure to groundwater contaminants of concern (COCs) is driven primarily by the exposure routes of ingestion inhalation of volatiles and dermal contact For a future on site resident this risk is on the order of $10^{-3}$ to $10^{-2}$ but applies only to exposures occurring directly at IHSS 119 1 Risk results excluding this source location are much lower for groundwater

The risk to a human receptor from exposure to surface soil COCs is driven primarily by the exposure routes of ingestion of vegetables ingestion of soil inhalation of particulates and dermal contact For a future on site resident this risk is on the order of $10^{-3}$ It should be noted however, that this risk is based on OU 1 sitewide average radionuclide concentrations These average radionuclide concentrations include a few areas of high contaminant concentrations (i e hotspots ) that are limited in extent and only exist within the boundaries of IHSSs 119 1 and 119 2 These hotspots are currently scheduled for remediation under an early removal action for OU 1 and will be remediated to measured background concentrations The risk to a future on site resident excluding the hotspots is on the order of $10^{-5}$ Risk results are summarized in Tables 1 3 and 1-4

## Table 1 3
## Summary of OU 1 Point Estimates of Carcinogenic Risk

| Scenario | Total Excess Cancer Risk | Dominant COC[a] | Dominant Pathway |
|---|---|---|---|
| **Current** | | | |
| On Site Worker (Security Specialist) | 1 x $10^{4}$ | Plutonium 239 240 | Inhalation of dust |
| Off Site Resident (Adult) | 2 x $10^{6}$ | Plutonium 239 240 | Inhalation of dust |
| **Standard Future** | | | |
| Future On Site Worker (Office) | 2 x $10^{3}$ | Plutonium-239 240 | Inhalation of dust |
| Future On Site Worker (Construction) | 4 x $10^{7}$ | 1 1 Dichloroethene | Inhalation of volatiles |
| On Site Ecological Researcher | 2 x $10^{3}$ | Plutonium-239 240 | Inhalation of dust |
| On Site Resident (Adult) | 3 x $10^{3}$ | Plutonium-239 240 | Inhalation of dust |
| **Other Future** | | | |
| On Site Resident (Adult) (Sitewide With Groundwater) | 6 x $10^{3}$ | 1 1 Dichloroethene | Ingestion of groundwater |
| On Site Resident (Adult) (Assuming Adequate Groundwater At Source) | 7 x $10^{2}$ | 1 1 Dichloroethene | Ingestion of groundwater |
| On Site Resident (Adult) (Groundwater At Source With Public Water) | 4 x $10^{2}$ | Plutonium 239 240 | Inhalation of dust |
| On Site Resident (Adult) (Without Source/Without Groundwater) | 5 x $10^{5}$ | Dibenzo(a h)anthracene | Ingestion of vegetables |

Plutonium concentrations are biased high by the presence of several hotspots which are currently being evaluated for removal Upon removal of the hotspots the dominant surface soil COC is no longer plutonium for those areas where the radionuclide hotspots drive the risk In these cases risks from surface soils will be approximately 5 x 10 as calculated for the on-site resident scenario without the source

## Table 1-4
## Summary of OU-1 Point Estimates of Noncarcinogenic Risk

| Scenario | Total Hazard Index | | Dominant COC | Dominant Pathway |
|---|---|---|---|---|
| | Child | Adult | | |
| **Current** | | | | |
| On Site Worker (Security Specialist) | N/A | $8 \times 10^{-5}$ | Pyrene | Dermal contact with soil |
| Off Site Resident | $1 \times 10^{-7}$ | $6 \times 10^{-8}$ | Fluorene | Ingestion of vegetables |
| **Standard Future** | | | | |
| Future On-Site Worker (Office) | N/A | $3 \times 10^{-3}$ | 1 1 1 Trichloroethane | Inhalation of volatiles through foundation |
| Future On Site Worker (Construction) | N/A | $1 \times 10^{-4}$ | 1 1 1 Trichloroethane | Inhalation of volatiles during excavation |
| On Site Ecological Researcher | N/A | $2 \times 10^{-3}$ | Pyrene | Dermal contact with soil |
| On Site Resident | $2 \times 10^{-2}$ | $5 \times 10^{-3}$ | 1 1 1 Trichloroethane | Inhalation of volatiles through foundation |
| **Other Future** | | | | |
| On Site Resident (Sitewide With Groundwater) | $2 \times 10^{+1}$ | $9 \times 10^{0}$ | Carbon Tetrachloride | Ingestion of groundwater |
| On-Site Resident (Assuming Adequate Groundwater At Source) | $3 \times 10^{+2}$ | $1 \times 10^{+2}$ | Carbon Tetrachloride | Ingestion of groundwater |
| On Site Resident (Groundwater At Source With Public Water) | $3 \times 10^{+1}$ | $1 \times 10^{+1}$ | Carbon Tetrachloride | Ingestion of groundwater |
| On Site Resident (Without Source/Without Groundwater) | $7 \times 10^{-3}$ | $3 \times 10^{-3}$ | Fluorene | Ingestion of vegetables |

1 5 2 Environmental Evaluation

As part of the overall BRA an environmental evaluation (EE) conducted to ascertain whether contamination resulting from RFETS activities in OU 1 may have impacted or could adversely impact ecological receptors in the vicinity where ecological receptors are operationally defined as plants and animals other than humans and domesticated species

COCs were selected for the EE based on a comparison of maximum concentrations of OU 1 contaminants to benchmark values COCs identified in the EE include VOCs PAHs PCB radionuclides and selenium The EE evaluated the impact that these COCs had on the following endpoints

- Vegetative Community
- Small Mammal Community
- Mule Deer Population
- Toxic Exposure to Top Predators

The results of the EE indicate that the concentrations of VOCs in groundwater and PAHs and PCBs in soils are potentially toxic to ecological receptors however the restricted distribution of these contaminants limits the duration and frequency of contact with receptors and therefore limits exposures

1 5 3 Risk Summary

As indicated by the PHE portion of the BRA risks to human receptors at OU 1 are primarily associated with exposure to groundwater COCs Although this medium is not available for current residential use this scenario presents the highest and only, unacceptable risk per the NCP guideline of $10^{-4}$ to $10^{-6}$ Environmental risks currently have not been identified by the Phase III RFI/RI and therefore do not warrant further examination

OU 1 risks are a result of widespread contamination found in low concentrations and in various media throughout the site The Phase III RFI/RI results indicate that for the most part individual IHSSs cannot be associated directly with any one contaminant group or area Table 1 5 lists the primary contaminants present at each IHSS and summarizes how these contaminants will be addressed in the CMS/FS

## 1 6 Interim Measures/Interim Remedial Actions

The IM/IRA that was completed for OU 1 consists of a french drain designed to collect contaminated alluvial groundwater from the operable unit and to prevent further downgradient migration of contaminants The IM/IRA included a geotechnical investigation that was performed in order to evaluate the site characteristics along the proposed french drain alignment (EG&G 1990) Construction of the french drain began in November 1991 and was completed in April 1992 The water treatment plant located in Building 891 is part of the IM/IRA and will be converted to sitewide uses Hereinafter this plant is referred to as the Building 891 water treatment plant

The french drain was constructed by excavating a trench approximately 1 435 feet in length (DOE 1994a) The trench was keyed into bedrock material that exhibited a hydraulic conductivity on the order of 1 x $10^{-6}$ cm/sec A permeable membrane was placed on the upgradient side of the drain and an impermeable polyvinyl chloride membrane was placed on the downgradient side of the drain A perforated pipe was placed along the drain to collect groundwater, and the drain was backfilled with gravel and then soil Currently, groundwater collected from the drain is fed into an ultraviolet and hydrogen peroxide (UV/$H_2O_2$) treatment unit for treatment of organic compounds Inorganic contaminants are removed via a series of ion exchange columns

An additional removal action is planned for OU 1 to remove surface soil radionuclide hotspots identified during the Phase III surface soil investigation The action is documented in a Proposed Action Memorandum (PAM) and is intended to eliminate the plutonium and uranium

## Table 1-5
## Summary of Primary IHSS Contaminants

| IHSS Number | Primary Contaminants[a] | Disposition |
|---|---|---|
| 102 | Groundwater contaminated with PCE and TCE | Considered in Building 881 Area |
| 103 | Possible groundwater and subsurface soils contaminated with low levels of PCE and TCE | Considered in Building 881 Area |
| 104 | Potential toluene in subsurface and groundwater wide array of PAHs | Not identified as a source no action required |
| 105 1 & 105 2 | Low levels of VOCs in groundwater PCE detected below detection limit, potential solvent contamination in soils at north end | Considered in Building 881 Area although not identified as a source |
| 106 | Groundwater contaminated with chlorinated solvents potential solvent contamination in soils at north end | Considered in Building 881 Area although not identified as a source |
| 107 | Groundwater contaminated with chlorinated solvents | Considered in Building 881 Area although not identified as a source |
| 119 1 & 119 2 | Groundwater contaminated with chlorinated solvents and selenium possible DNAPL sources in subsurface radionuclide hotspots | Considered under IHSS 119 1 and Area East of 119 2 |
| 130 | Radionuclide-contaminated soil and asphalt PAHs in subsurface soils | No risk pathway for rads and PAHs in subsurface soils no action required Not identified as a source of VOCs |
| 145 | Groundwater contaminated with chlorinated solvents potential low level rad contamination | Considered in Building 881 Area although not identified as a source |

[a] Radionuclide and PAH contamination in near surface soils is not identified in this table due to the widespread and consistent nature of the contamination, indicating a source outside of OU 1 and unrelated to OU 1 disposal activities

hotspots that are currently evaluated as part of the sitewide risk This removal action is scheduled to be completed prior to completion of the proposed plan for OU 1 For the purposes of alternative development it will be assumed that the hotspots are not present This assumption lowers the sitewide risk from surface soil contaminants to $10^{-5}$ and below for all exposure scenarios

## 2 0 IDENTIFICATION AND SELECTION OF TECHNOLOGIES AND REPRESENTATIVE PROCESS OPTIONS

This section summarizes the results of the identification screening evaluation and selection of technologies and representative process options used in the development of remedial action alternatives for OU 1 Information on how these activities are conducted is included in the CERCLA RI/FS guidance In general, the guidance identifies the following steps for selecting representative process options

- Develop media specific RAOs
- Develop media-specific GRAs
- Identify volumes and/or areas of the media which require GRAs
- Identify and screen technologies and process options applicable to each GRA
- Evaluate process options within each technology type to select a representative option for developing remedial action alternatives

This section summarizes how these steps were applied to OU 1 Originally two technical memoranda were prepared to seek input from the regulatory agencies on RAOs preliminary remediation goals (PRGs), and the alternative development process A final version of TM #10 and a draft final version of TM #11 were submitted to the agencies in April 1994 Comments were received on both documents and were incorporated in this report where appropriate The technical memoranda will not be resubmitted but are available for review in the administrative record

Elements from both technical memoranda are included in this section and in Section 3 0 particularly where specific comments are being addressed However, the detailed calculations involved in estimating PRGs and the screening and evaluation of technologies and process options are not included in this report This information is presented in TMs #10 and #11 and is summarized in this section and Section 3 0

## 2 1 Contaminants of Concern

The list of contaminants originally identified in the Phase III RFI/RI is presented in Section 1 0 of this report Potential contaminants identified early in the RFI/RI process were subjected to a multi level screening process that identified COCs for inclusion in the PHE and EE The screening process shortened the list of potential contaminants to consider further as risk contributors the process is presented in detail in the Phase III RFI/RI report Contaminants that survived the risk based screening process were designated as COCs in the BRA

The PHE and EE present the results of COC screenings that were performed to identify potential risk contributors to human and ecological receptors respectively The COCs identified in the EE were the following

- carbon tetrachloride
- 1 1 dichloroethene
- tetrachloroethene
- 1 1 1 trichloroethane
- trichloroethene
- toluene
- selenium
- PAHs
- PCBs
- americium
- plutonium
- uranium

Because these contaminants do not contribute a significant risk to ecological receptors and no adverse impacts are currently identified in the EE they are not evaluated separately in this report

However groundwater COCs identified in the PHE are a potential concern at OU 1 Risks associated with exposure to these COCs exceed $10^{-4}$ at IHSS 119 1 The following COCs were identified for groundwater

- carbon tetrachloride
- 1 1 dichloroethene
- tetrachloroethene
- 1 1 1 trichloroethane
- selenium

Surface soil COCs were also identified in the PHE including PAHs PCBs and radionuclides However radionuclide contaminants associated with windblown dispersion of OU 2 contaminants (from the 903 Pad) are not addressed in this report The radionuclide contaminants consist primarily of low concentrations of americium and plutonium spread across several operable units These radionuclides must be addressed as a whole through the medium and source where they originate Therefore, in order to develop appropriate remedial action alternatives the administrative transfer of radionuclide contaminants to OU 2 is currently in progress

In addition several radionuclide hotspots were identified in OU 1 as risk contributors These hotspots are currently scheduled for remediation under a removal action and are therefore not considered for alternative development

PAHs and PCBs are the only COCs remaining for evaluation in surface soils Excluding radionuclides the highest risk associated with PAHs and PCBs in OU 1 surface soils is on the order of $10^{-5}$ This is similar to background risks from PAHs in urban areas and is within the acceptable risk range specified in the NCP ($10^{-4}$ to $10^{-6}$) Because PAHs and PCBs in surface soils do not present an unacceptable risk and cannot be physically isolated from the radionuclides in surface soils being addressed under OU 2 these contaminants are not included in the development of remedial action alternatives

As discussed in Section 1 0, the BRA indicates that no media other than groundwater and surface soil result in a risk greater than $10^{-6}$ nor do they result in adverse impacts to environmental receptors In addition surface water and sediments evaluated in the BRA are being addressed through OU 5 For these reasons no COCs are identified for any media except groundwater and surface soils Subsurface soil COCs are identified as a possible source of groundwater contamination and are addressed through the groundwater COCs RAOs and GRAs

## 2 2 Summary of Remedial Action Objectives

RAOs were developed using appropriate regulatory guidelines (i e CERCLA RI/FS guidance and the NCP) and by examining the COCs identified in Section 2 1 and their associated exposure pathways Briefly the RAOs for OU 1 are the following

1) Prevent the inhalation of ingestion of, and/or dermal contact with VOCs and inorganic contaminants in groundwater that would result in a total excess cancer risk greater than $10^{-4}$ to $10^{-6}$ for carcinogens and/or a hazard index greater than or equal to one for non carcinogens

2) Minimize further degradation of groundwater beneath OU 1 by eliminating and/or containing residual subsurface soil DNAPLs to the maximum extent practicable

3) Prevent the inhalation of ingestion of and/or dermal contact with PAHs PCBs, and radionuclides in surface soils that would result in a total excess cancer risk greater than $10^{-4}$ to $10^{-6}$ for carcinogens and/or a hazard index greater than or equal to one for non carcinogens

4) Prevent exposure to carcinogenic radionuclides in surface soil hotspots that would result in an excessive short term risk to a human receptor

These RAOs are used to determine what area or areas of OU 1 require remedial action evaluation and are quantified through the use of PRGs The third and fourth RAOs listed above are already being addressed through the OU 1 surface soil hotspot removal action This action along with the administrative transfer of other radionuclides in surface soils to OU 2 will result in a residual risk level within the acceptable risk range of $10^{-4}$ to $10^{-6}$ Therefore the focus of this report is on meeting the first and second RAO which are concerned with groundwater

## 2 3 Development of Preliminary Remediation Goals

PRGs are generally identified through use of readily available information such as chemical specific ARARs or other reliable information (EPA 1990a) Where ARARs or to-be considered (TBC) criteria are not available PRGs are developed on the basis of a $10^{-6}$ point of departure risk for each chemical within a given medium This also applies when ARARs are not considered sufficiently protective because of the presence of multiple contaminants or multiple pathways of exposure Note that PRGs developed at this stage are considered initial goals which may be revised through the course of the CMS/FS The following sections present the sources of information used for identifying appropriate PRGs for OU 1 both chemical specific ARARs and risk-based cleanup goals Existing potential OU 1 chemical specific ARARs are currently the basis for alternative development

### 2 3 1 Potential Chemical Specific Applicable or Relevant and Appropriate Requirements

CERCLA Section 121(d)(2) provides a statutory basis for determining ARARs in a remedial action context concerning hazardous substances, pollutants, or contaminants that will remain on site

> If any standard requirement criteria or limitation under any federal environmental law or any [more stringent] promulgated standard requirement criteria or limitation under a state environmental or facility siting law is legally applicable to the hazardous substance concerned or is relevant and appropriate under the circumstances of the release or threatened release of such hazardous substance pollutant or contaminant the remedial action shall require at the completion of the remedial action a level or standard of control for such hazardous substance pollutant or contaminant which at least attains such legally applicable or relevant and appropriate standard requirement criteria or limitation [42 United States Code (USC) ----§ 9621(d)(2) ]

where applicable requirements" are those

> cleanup standards standards of control or other substantive environmental protection requirements criteria or limitations promulgated under federal environmental or state environmental or facility siting laws that specifically address a

hazardous substance pollutant contaminant remedial action location or other circumstance found at a CERCLA site Only those state standards that are identified by a state in a timely manner and that are more stringent than federal requirements may be applicable

According to the NCP and the *CERCLA Compliance with Other Laws Manual* (EPA 1988b)

Relevant and appropriate requirements are those cleanup standards standards of control, and other substantive requirements criteria, or limitations promulgated under federal environmental or state environmental or facility siting laws that while not applicable to a hazardous substance pollutant contaminant remedial action location or other circumstance at a CERCLA site address problems or situations sufficiently similar to those encountered at the CERCLA site so that their use is well suited to the particular site Only those state standards that are identified in a timely manner and are more stringent than federal requirements may be relevant and appropriate

Chemical specific ARARs were identified in accordance with CERCLA guidance and the requirements of the NCP [see 40 Code of Federal Regulations (CFR) Part 300 Subsection 430(e)(2)(i)] Chemical specific requirements under a variety of Federal and state laws were reviewed to identify potential groundwater and surface soil chemical specific ARARs

Current Groundwater Classification

The Colorado Water Quality Control Commission (CWQCC) designated the Quaternary and Rocky Flats Aquifers beneath the RFETS as domestic use quality agricultural use quality and surface water protection according to 3 12 7 of 5 Colorado Code of Regulations (CCR) 1002 8 Subsection 3 12 7 The intent of these classifications is to protect specified groundwater from uncontrolled degradation and thereby protect existing and future uses of groundwater (5 CCR 1002 8 Subsection 3 11 9) Furthermore groundwater is classified domestic use or agricultural use quality if

the groundwater is either used or reasonably likely to be used for domestic or agricultural purposes within the specified area or

the most recent State Engineer s well records or applicable court decrees reveal that groundwater is permitted or decreed for such uses within the specified area (5 CCR 1002 8 Subsection 3 11 4)

The Phase III RFI/RI report does not support the CWQCC conclusion that there is groundwater beneath OU 1 which could be used as a drinking water supply Included in the Phase III RFI/RI report are water production capability simulations and well production tests which conclude that neither the Rocky Flats Alluvium nor the Arapahoe Aquifers beneath OU 1 is capable of producing sufficient water for even domestic purposes In addition a letter from the Office of the Colorade State Engineer confirms that the conclusion that neither aquifer (referring to the Rocky Flats Alluvium and the Arapahoe Aquifer) is a potential source for domestic water supplies in the 881 Hillside area is valid when considering future land use (see Appendix F) The Colorado State Engineer s letter dated March 12 1992 is in reference to the water production capability simulations and well production tests that were included in the Phase III RFI/RI report (see Appendix F)

DOE may petition the CWQCC when appropriate to consider changing the water quality classification beneath OU 1 Documentation of potential water use and quality of water in the Quaternary and Rocky Flats Aquifers beneath the site will be presented to the Commission for reconsideration of the current use classifications

Potential Groundwater ARARs

The groundwater beneath the RFETS is currently classified for domestic use quality TM #10 listed Federal maximum contaminant levels (MCLs) as the chemical specific ARARs for OU 1 CDPHE commented on TM #10 that the State s MCL standards should be ARARs The State implements the Federal Safe Drinking Water Act (SDWA) through its drinking water program therefore state drinking water standards are presented in Table 2 1 as potential chemical specific ARARs for OU 1 The Superfund Amendments and Reauthorization Act (SARA) and the NCP rules require classification of non zero maximum contaminant level goals (MCLGs) as potential chemical specific ARARs Federal non zero MCLGs for OU 1 contaminants are the same as the State MCLs listed in Table 2 1

**Table 2-1**
**Potential Groundwater Chemical Specific ARARs**
**State Drinking Water Standards[a]**
**($\mu g/\ell$)**

| Chemical[b] | State MCL |
|---|---|
| **Volatile Organic Compounds** | |
| Carbon Tetrachloride | 5 |
| Chloroform (total trihalomethanes) | <100 |
| 1 1 Dichloroethane | N/A |
| 1 2 Dichloroethane | 5 |
| 1 1 Dichloroethene | 7 |
| 1 2 Dichloroethene | N/A |
| cis 1 2 Dichloroethene | 70 |
| Tetrachloroethene | 5 |
| Toluene | 1 000 |
| Total Xylenes | 10 000 |
| 1 1 1 Trichloroethane | 200 |
| 1 1 2 Trichloroethane | 5 |
| Trichloroethene | 5 |
| **Metals** | |
| Selenium | 50 |
| Vanadium | N/A |

a From CRS 25-1 107 25-1 108 25-1 109 and 25-1 114
b All contaminants originally identified by the Phase III RFI/RI are listed
c Federal MCLs are numerically equivalent to these State MCLs

State groundwater standards are identified in Table 2 2 and are TBCs for OU 1 The standards were evaluated against the definition of ARARs in the NCP (40 CFR 300 5) The state groundwater standards are not assessed ARARs because the classifications requiring those standards have not been applied consistently throughout the state and thus fail the NCP criteria of general applicability in 40 CFR 300 400(g)(4)

Potential Surface Soil ARARs

Soil chemical specific ARARs requirements under State and Federal laws do not exist for the contaminants identified in OU 1 (i e there are no established protective levels for surface soil contamination based on risks to human health and/or the environment) with the exception of PCBs under Toxic Substances Control Act (TSCA) However TSCA requirements for pre-1987 cleanups are determined on a case by case basis depending on the potential for contamination Spills after 1987 define clean soil as containing less than 1 mg/kg PCBs (40 CFR 761 120 and 761 125) The concentrations of PCBs found in OU 1 are below this concentration except in one instance which is at a 1 2 mg/kg concentration Therefore it was considered to be within an acceptable range of determining a cleanup level Accordingly no chemical specific ARARs are identified for this medium

2 3 2 Preliminary Remediation Goals Based on $10^{-6}$ as the Point-of Departure

In TM #10 both groundwater and surface soil PRGs were estimated for OU 1 Other media involving surface water and sediments were not considered for PRG development as part of the OU 1 CMS/FS since they as well as subsurface soils do not present a direct risk greater than $10^{-6}$ nor a hazard index greater than one and therefore do not warrant risk based PRGs

Groundwater and surface soil PRGs were estimated in TM #10 for the following exposure scenarios

- Future On Site Resident
- Commercial/Industrial Workers

**Table 2 2**
**Statewide and Basin-Specific Groundwater Standards[a]**
**($\mu g/\ell$)**

| Chemical[1] | State Standard | Practical Quantitation Limit |
|---|---|---|
| **Volatile Organic Compounds** | | |
| Carbon Tetrachloride | 0 3 | 1 0 |
| Chloroform | 6/0 19[b] | 1 0 |
| 1 1 Dichloroethane | — | — |
| 1 2 Dichloroethane | 0 4 | 1 0 |
| 1 1 Dichloroethene | 7 | 1 0 |
| 1 2 Dichloroethene | — | — |
| cis 1 2 Dichloroethene | 70[c] | 1 0 |
| Tetrachloroethene | 5/0 8b[b] | 1 0 |
| Toluene | 1 000 | 1 0 |
| Total Xylenes | 10 000[c] | 1 |
| 1 1 1 Trichloroethane | 200 | 1 0 |
| 1 1 2 Trichloroethane | 3/0 6[b] | 1 0 |
| Trichloroethene | 5 | 1 0 |
| **Metals** | | |
| Selenium | 10[d]/20[e] | — |
| Vanadium | 100[e] | — |

1 All contaminants originally identified by the Phase III RFI/RI are listed
a CDPHE/Water Quality Control Commission Basic Standards for Groundwater 3 11 0 effective 3/30/94
b CDPHE/Water Quality Control Commission Classification and Water Quality Standards for Groundwater 3 12 0 effective 1/31/94
c Listed as drinking water MCL in state groundwater standards Table A
d Measured as a dissolved concentration
e Agricultural standard

The ecological reserve scenario was not used for estimating PRGs because the scenario does not apply to groundwater and is identical to the commercial/industrial scenario in terms of exposures for surface soils Tables 2 3 and 2 4 present the risk based PRGs estimated for groundwater and surface soils respectively (for the COCs identified in the BRA) Table 2 5 compares the groundwater PRGs identified using chemical specific and risk based PRGs For the purposes of OU 1 state MCLs are currently used to evaluate remedial action Risk based PRGs are presented for information only In addition the geometric mean concentrations are presented for both sitewide and IHSS 119 1 only

In addition to establishing PRGs that comply with ARARs and protect human health and the environment DOE plans to reduce exposures and the risk associated with residual contamination during remedial actions at OU 1 to levels that are as low as reasonably achievable (ALARA) considering appropriate technical economic and social constraints In applying the ALARA process at OU 1 PRGs are combined with technical and economic considerations to identify the levels of risk reduction that might reasonably be achieved These criteria are only applicable to surface soils which may be disturbed during implementation of remediation activities at OU 1

The ALARA process includes both planning and field components The discussions presented in this section are consistent with the planning component of ALARA in which PRGs are estimated for residual contamination based on hypothetical exposures This initial analysis will be used to support implementation of ALARA in the field where based on specific field conditions additional contamination might be reduced to below levels determined in the planning phase

As a general standard for radiological exposures DOE also requires compliance with all Federal requirements for limiting doses from specific exposure modes DOE Order 5400 5 establishes standards for nonspecific radiological exposures These standards require that the effective dose equivalent (EDE) to a member of the public not exceed 100 mrem/year above background from all non-occupational exposure routes and that these exposures be reduced to ALARA levels

## Table 2 3
## Groundwater
## Risk-Based Preliminary Remediation Goals
## ($\mu g/\ell$)

| Chemical | Preliminary Remediation Goal by Scenario[a] | |
|---|---|---|
| | Future On-Site Resident | Commercial/ Industrial Worker |
| **Volatile Organic Compounds** | | |
| Carbon Tetrachloride | 0 658 | 13 8 |
| 1 1 Dichloroethene | 0 150 | 1 99 |
| Tetrachloroethene | 1 85 | 683 |
| 1 1 1 Trichloroethane | 3120 | 293 684 |
| **Metals** | | |
| Selenium | 183 | N/A |

[a] The ecological reserve researcher scenario does not apply to this medium

## Table 2-4
## Surface Soils
## Risk-Based Preliminary Remediation Goals
## (mg/kg)

| Chemical | Preliminary Remediation Goal by Scenario[a] | |
|---|---|---|
| | Future On-Site Resident | Commercial/ Industrial Worker |
| **Polynuclear Aromatic Hydrocarbons** | | |
| Acenapthene | 326 | 2 658 |
| Benzo(a)anthracene | 0 168 | 1 378 |
| Benzo(a)pyrene | 0 156 | 0 137 |
| Benzo(b)fluoranthene | 0 307 | 0 070 |
| Benzo(k)fluoranthene | 1 98 | 1 33 |
| Dibenzo(a h)anthracene | 0 017 | 0 134 |
| Fluoranthene | 1 010 | 1 771 |
| Fluorene | 251 | 1 745 |
| Pyrene | 634 | 1 342 |
| **Polychlorinated Biphenyls** | | |
| AROCLOR 1254 | 0 050 | 0 125 |
| **Radionuclides[b]** | | |
| Americium 241 | 1 80 | 4 12 |
| Uranium 233 234 | 4 34 | 6 81 |
| Uranium 238 | 2 29 | 3 55 |
| Plutonium 239 240 | 1 25 | 3 68 |

[a] The ecological reserve researcher scenario results in the same PRGs as the commercial/industrial worker scenario
[b] Radionuclides are reported in pCi/g

## Table 2 5
## Comparison of Risk-Based PRGs, ARARs, TBCs, and Existing Concentrations
## ($\mu g/\ell$)

| Chemical[1] | Existing Concentration (grand mean)[2] | IHSS 119 1 Concentration (grand mean)[2] | Risk Based PRG[3] | State MCL[4] | State Groundwater Standard | PQL[5] | |
|---|---|---|---|---|---|---|---|
| | | | | | | RFETS | CDPHE |
| **Volatile Organic Compounds** | | | | | | | |
| Carbon Tetrachloride | 81 20 | 360 6 | 0 658 | 5 | 0 3 | 5 | 1 0 |
| Chloroform | 4.68 | 16 | 2.33 | <100 | 6/0.19[e] | 5 | 1 0 |
| 1 1-Dichloroethane | 2.10 | 4.94 | 2,670 | — | — | 5 | — |
| 1,2-Dichloroethane | 6.10 | 3.7 | 0.780 | 5 | 0.4 | 5 | 1 0 |
| 1 1 Dichloroethene | 283 23 | 1 270 | 0 150 | 7 | 7 | 5 | 1 0 |
| 1,2-Dichloroethene | NA | NA | 218 | — | — | 5 | 1 0 |
| cis-1,2-Dichloroethene | 0.52 | 2.62 | 225 | 70 | 70[b] | — | 1 0 |
| Tetrachloroethene | 103 48 | 459 5 | 1 85 | 5 | 5/0 8 | 10 | 1 0 |
| Toluene | 4.68 | 16.48 | 3,670 | 1,000 | 1,000 | 5 | 1 0 |
| Total Xylenes | 3.23 | 6.09 | 1,210 | 10,000 | 10,000[b] | 5 | 1 |
| 1 1 1 Trichloroethane | 363 29 | 1 630 1 | 3 120 | 200 | 200 | 5 | 1 0 |
| 1,1,2-Trichloroethane | 2.69 | 7.67 | 125 | 5 | 3/0.6[e] | 5 | 1 0 |
| Trichloroethene | 371.65 | 1,667 | 7.43 | 5 | 4 | 5 | 1.0 |
| **Metals** | | | | | | | |
| Selenium | 283 4 | 503 2 | 183 | 50 | 10[d]/20[e] | 5 | — |
| Vanadium | 8.68 | 43.3 | 256 | — | 100[e] | 50 | — |
| **Semivolatile Organic Compounds** | | | | | | | |
| Naphthalene | NA | NA | 888 | — | — | 10 | — |

1 Shaded contaminants were not designated as COCs by the BRA portion of the Phase III RFI/RI
2 From Phase III sampling results in Section 4 Final Phase III RFI/RI Report, June 1994
3 Based on the Future On-Site residential scenario
4 From CRS 25-1 107 25-1 108 25-1 109 and 25-1 114
5 Practical Quantitation Limits (PQLs) are reported for both the RFETS and the CDPHE.
CDPHE/Water Quality Control Commission, Basic Standards for Groundwater 3 11 0 effective 3/30/94
b Listed as drinking water MCL in State groundwater standards Table A
CDPHE/Water Quality Control Commission Classification and Water Quality Standards for Groundwater 3 12 0 ffective 1/31/94
d Measured as a dissolved concentration
Agricultural standard.

Both ALARA and DOE Order 5400 5 requirements are appropriate for handling surface soils in OU 1 and will be addressed further under OU 2 remedial actions

## 2 4 General Response Actions

GRAs are general waste management strategies that are designed to satisfy remedial action objectives Examples of GRAs include treatment containment excavation and extraction GRAs are medium specific and therefore a list of GRAs will be developed for each medium of concern For OU 1, GRAs were only identified for the groundwater medium Because subsurface soils are a potential continual source of groundwater contamination they are included in discussions involving groundwater GRAs and remedial action alternatives

### 2 4 1 Surface Soil General Response Actions

As indicated in the Phase III RFI/RI report and summarized in Section 1 0 of this report surface soil PAHs PCBs and radionuclides will result in an acceptable risk of $10^{-4}$ to $10^{-6}$ when the hotspots are removed Because the hotspots will be removed before implementation of any remedial actions and because surface soil radionuclides will be addressed specifically under OU 2, the surface soil medium has been eliminated from further consideration in this report

### 2 4 2 Groundwater General Response Actions

The GRAs identified for the OU 1 groundwater medium are no action institutional controls containment removal in situ treatment of chlorinated solvents, ex situ treatment of chlorinated solvents in situ treatment of inorganics and ex situ treatment of inorganics These GRAs target the contaminant groups discussed in the RAO for groundwater A brief description of each GRA is provided below

- *No Action* Required by CERCLA as a benchmark for comparison against other remedial action alternatives This implies that no direct action will be taken to alter the existing situation other than short and long term monitoring of site conditions

- *Institutional Controls* - Refers to controls based on legal and/or management policies which minimize the public s exposure to potential contaminants Examples include controlling site access restricting land use and restricting access to groundwater

- *Containment* For groundwater containment would consist of actions which minimize the flux of vapor phase VOCs to the surface and/or minimize the migration of groundwater contaminants across site boundaries

- *Removal* For OU 1 removal implies extraction of contaminated groundwater for treatment in the existing Building 891 water treatment system or other facilities This also includes the excavation of soils to locate potential subsurface soil DNAPL zones and to extract contaminated groundwater

- *In Situ Treatment of Chlorinated Solvents* In general in situ treatment technologies seek to treat contaminants in place without extraction or removal of large volumes of groundwater or soil Treatment would seek to remove destroy and/or immobilize contaminants through biological chemical or physical means This category includes extraction technologies such as soil vapor extraction and in situ heating and includes aboveground treatment of off gas and address as both groundwater and subsurface soil contamination

- *Ex Situ Treatment of Chlorinated Solvents* This GRA is similar to in situ treatment except that contaminants would be extracted/removed before treatment Treated groundwater would be discharged through existing channels (i e the existing Building 891 water treatment system)

- *In Situ Treatment of Inorganics* This GRA is similar to the in situ treatment of chlorinated solvents In this case treatment would seek to immobilize contaminants through chemical or physical means

- *Ex Situ Treatment of Inorganics* This GRA is similar to in situ treatment of inorganics In this case treatment would seek to extract and/or immobilize contaminants through chemical or physical means Treated groundwater would be discharged through existing channels (i e the existing Building 891 water treatment system)

### 2 4 3 Volume and Area Estimates

Based on the results of the OU 1 Phase III RFI/RI report and the BRA in particular contaminated groundwater in OU 1 was found to contribute a significantly higher risk to those receptors exposed to groundwater beneath a specific portion of IHSS 119 1 than to receptors exposed to groundwater beneath other locations in OU 1 IHSS 119 1 was designated a source location in the PHE for this reason Other areas of the operable unit contain groundwater contaminant concentrations above detection limits however the concentrations are greatest at this IHSS

The quantity of groundwater requiring remedial action in the IHSS 119 1 source area cannot be calculated directly because of seasonal variations in the water table Instead a lower bound was estimated using computer codes that compared the bedrock topography beneath the IHSS to the water level data from wells located in this area The wells used to identify and delineate this area were 0487 0974 1074 4387 32591 and 37991

The Phase III RFI/RI report contains several saturated thickness maps for OU 1 during a typical dry period These maps were used to estimate the volume of contaminated groundwater in the source location when groundwater levels were at their lowest Using an average porosity of 0 10 (DOE 1994a) the volume of groundwater estimated to be present in the southwest corner of IHSS 119 1 during the dry season is 80 000 gallons This volume represents a single pore volume although more than one pore volume would likely have to be removed to achieve RAOs

In addition the Phase III RFI/RI report estimated that the volume of available groundwater in OU 1 is between 5 0 and 5 8 acre-feet (1 6 and 1 9 million gallons) The volume of groundwater estimated to be beneath IHSS 119 1 and the volume of groundwater beneath OU 1 are used to estimate remediation requirements however because groundwater elevations in OU 1 are highly dependent on seasonal variations in precipitation these values are engineering estimates only

To address the potential residual DNAPL sources assumed to be present in IHSS 119 1 subsurface soils a volume calculation was conducted for this medium at IHSS 119 1 The amount of soil requiring remediation was estimated by visually inspecting the potential source areas described in the Phase III RFI/RI report and presented in Figure 1 3 of this report and by assuming that subsurface soil remediation activities would attempt to remediate saturated zone soils to a depth of five feet into bedrock Figure 2 1 depicts the potential soil excavation area identified for IHSS 119 1 The amount of contaminated subsurface soils cannot be calculated due to the limited data available for this medium This limited data is typical of sites contaminated with residual DNAPLs The excavation area however is estimated to contain approximately 20 000 cubic yards of soil

## 2 5 Identification and Screening of Technologies and Process Options

Appendix A contains the tables and figures originally presented in TM #11 for the identification and screening of technologies and process options This section summarizes the technologies and process options that were identified for remediation of OU 1 and also describes options that were maintained for further evaluation Note that a process option chosen to develop an alternative is considered a representative process option only The alternative might not be implemented with the specific process option The selected process option represents a class of options that might be implemented

The technologies and process options originally examined for use at OU 1 include the following

No Action

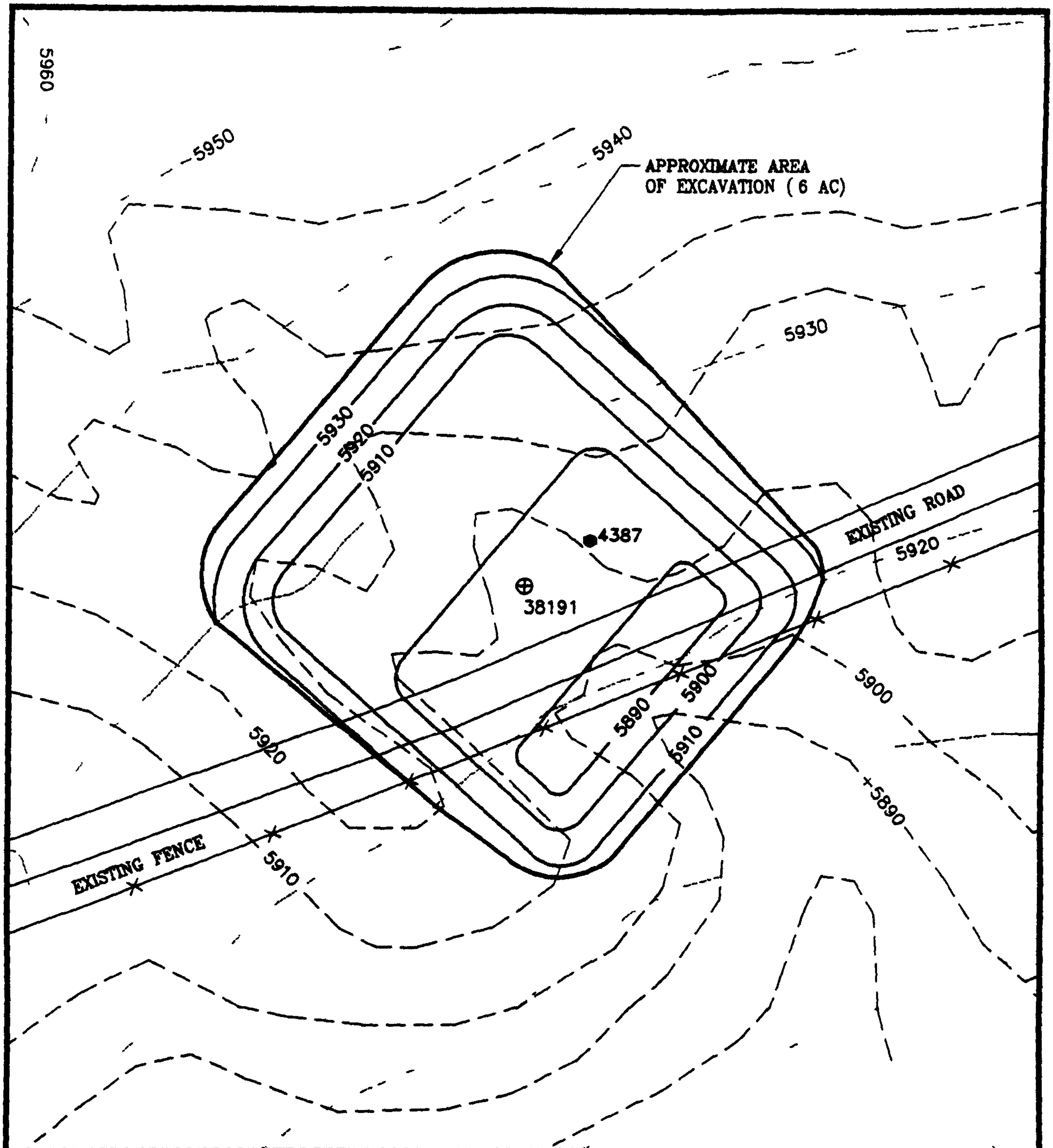
- Monitoring
  - Groundwater monitoring

Institutional Controls

- Access restrictions
  - Legal restrictions on well placement
  - Legal restrictions on land use

Containment

- Vertical subsurface flow control
  - Subsurface drains
  - Grout curtains
  - Slurry walls
  - Sheet pilings




EXPLANATION

SURFACE CONTOUR
BEDROCK CONTOUR
EXCAVATION CONTOUR
4387 ALLUVIAL WELL
38191 PIEZOMETER

N

0 25 50
SCALE 1" 50'

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Potential
Soil Excavation Area

Figure 2-1

OU1-EXC2 DWG

- Cryogenic barrier

- Horizontal subsurface flow control
  - Grout injection
  - Block displacement

- Vapor containment
  - Surface cap
  - Environmental isolation enclosure

Removal

- Passive removal
  - Subsurface drains

- Active removal
  - Horizontal and/or vertical extraction wells or sumps

- Excavation
  - Loader/excavator/dozer

In—situ Treatment of Chlorinated Solvents

- Biological
  - Bioremediation

- Chemical
  - Polymerization
  - Chemical oxidation

- Physical
  - Hot air/steam stripping with mechanical mixing
  - Air sparging
  - Soil vapor extraction
  - Permeable treatment beds
  - In situ adsorption with wells (proprietary process)
  - Radio frequency/ohmic heating

Ex situ Treatment of Chlorinated Solvents

- Biological
  - Bioremediation

- Chemical
  - Solvent extraction

- Ultraviolet photolysis with chemical oxidation

- Physical
  - Gamma irradiation
  - Activated carbon or carbonaceous adsorbents
  - Air stripping
  - Membrane processes
  - Hot air/steam stripping
  - Evaporation
  - Freeze crystallization

- Thermal
  - Incineration
  - Plasma arc discharge
  - Catalytic oxidation

In situ Treatment of Inorganics

- Physical
  - Electrokinesis

Ex situ Treatment of Inorganics

- Physical
  - TRU clear (proprietary process)
  - Oxidation/reduction
  - Ferrite process
  - Magnetic separation

- Chemical
  - Freeze crystallization
  - Ion exchange
  - Evaporation
  - Membrane processes
  - Electrocoagulation
  - Precipitation

As described in TM #11 these technologies and process options were systematically screened to reduce the number to a smaller and more representative number appropriate for the preparation of remedial alternatives The screening was accomplished by examining the technical implementability of each technology and/or process option at OU 1 (see Appendix A) Technologies and/or process options that were maintained for further evaluation are listed below

No Action

- Monitoring
  - Groundwater monitoring

Institutional Controls

- Access restrictions
  - Legal restrictions on well placement
  - Legal restrictions on land use

Containment

- Vertical subsurface flow control
  - Subsurface drains

- Vapor containment
  - Surface cap
  - Environmental isolation enclosure

Removal

- Passive removal
  - Subsurface drains

- Active removal
  - Horizontal and/or vertical extraction wells or sumps

- Excavation
  - Loader/excavator/dozer

In situ Treatment of Chlorinated Solvents

- Biological
  - Bioremediation

- Physical
  - Hot air/steam stripping with mechanical mixing
  - Air sparging
  - Soil vapor extraction
  - Radio frequency/ohmic heating

Ex situ Treatment of Chlorinated Solvents

- Biological

- — Bioremediation

- Chemical
  - — Ultraviolet photolysis with chemical oxidation

- Physical
  - — Activated carbon or carbonaceous adsorbents
  - — Air stripping
  - — Hot air/steam stripping

- Thermal
  - — Plasma arc discharge
  - — Catalytic oxidation

In situ Treatment of Inorganics

- Physical
  - — Electrokinesis

Ex situ Treatment of Inorganics

- Physical
  - — TRU clear (proprietary process)
  - — Oxidation/reduction
  - — Ferrite process

- Chemical
  - — Ion exchange
  - — Membrane processes
  - — Electrocoagulation
  - — Precipitation

## 2 6 Evaluation and Selection of Representative Process Options

Technologies and process options determined to be implementable and applicable for remediation of OU 1 were subjected to a more detailed evaluation to determine which process options should be used to develop alternatives The evaluation was performed by comparing the ability of each process option to satisfy the given criteria under the same technology type and GRA The criteria used to evaluate process options were effectiveness, implementability and cost (see Appendix A) Any process option that survived the initial screening could be incorporated into an established remedial action alternative in the future

Based on the evaluation of process options the following technologies and process options were selected for alternative development

No Action

- Monitoring
  - Groundwater monitoring

Institutional Controls

- Access restrictions
  - Legal restrictions on well placement
  - Legal restrictions on land use

Containment

- Vertical subsurface flow control
  - Subsurface drains

- Vapor Containment
  - Surface cap
  - Environmental isolation enclosure

Removal

- Passive removal
  - Subsurface drains

- Active removal
  - Horizontal and/or vertical extraction wells or sumps

- Excavation
  - Loader/excavator/dozer

In situ Treatment of Chlorinated Solvents

- Physical
  - Hot air/steam stripping with mechanical mixing
  - Soil vapor extraction
  - Radio Frequency/ohmic heating

Ex situ Treatment of Chlorinated Solvents

- Chemical
  - Ultraviolet photolysis with chemical oxidation

Ex situ Treatment of Inorganics

- Chemical
  - Ion exchange

The evaluation of process options to treat extracted groundwater favored the selection of the existing Building 891 water treatment system Since the system has been proven to effectively treat the COCs present in OU 1 groundwater at their current concentrations and the capital costs have already been incurred for designing and constructing this system this process option is the most favorable for aboveground treatment of groundwater If necessary the system may also be used for other operable units with minor modifications

In addition the limited availability of groundwater and the complex nature of the bedrock system beneath OU 1 favored treatment by process options that would extract residual sources (e g DNAPL zones) to the greatest extent possible while minimizing the potential for forcing contaminants further into the bedrock system Therefore process options that required the injection of additional fluids into the subsurface (e g bioremediation and soil flushing), were not favorable Standard and thermally-enhanced vapor extraction process options were selected for alternative development and will be used in conjunction with limited groundwater pumping to remove contaminated groundwater and potential residual DNAPLs from OU 1 subsurface soils

Other options originally retained for alternative development included excavation and capping and were retained to provide conceptual variety to the alternatives presented for remediation of OU 1 Excavation could be used to remove subsurface soils to locate pools of contaminated groundwater and to ensure that any residual DNAPL zones are removed Capping on the other hand would attempt to limit the mobility of vapor phase contaminants thereby minimizing the risk from one of the primary risk pathways, inhalation of groundwater volatiles These options are further described in the discussion of alternatives in Section 3 0

Process options were also retained that would result in the assembly of limited or minimal action alternatives and include groundwater monitoring use of the existing french drain system and institutional controls These options are also discussed further in Section 3 0

Although it is currently undergoing treatability studies at RFETS bioremediation was not included in the development of remedial action alternatives for the following reasons

- The effectiveness of bioremediation at OU 1 is limited by the nature of the contaminants identified Although laboratory studies have shown up to 90 percent reduction of TCA and TCE concentrations under ideal conditions researchers are skeptical as to the full scale applicability of bioremediation under field conditions stating that implementation of biodegradation of chlorinated hydrocarbons in field situations may be limited by the toxicity of high concentrations of these compounds to microorganisms and by the slow rate of degradation possible (Baker et al 1994)

- PCE, a major OU 1 contaminant is a highly refractory compound (resistant to decay) for which there is no established field method for degradation at rates which make treatment practical

- Bioremediation is not effective in treating inorganics such as selenium An aboveground treatment system could be used to remove selenium from extracted groundwater however this would most likely limit the effectiveness of reinjection systems that recycle nutrients or non indigenous bacteria

- Site conditions at OU 1 particularly fluid circulation, limit the technical implementability of bioremediation at OU 1 The Phase III RFI/RI demonstrates the lack of a consistent, defined water source beneath IHSS 119 1 Well and borehole data in the area have indicated varying water table levels and depths of saturated zones Implementation of bioremediation at OU 1 would require injection of large volumes of water to provide nutrients and/or non indigenous bacteria to treatment zones This might mobilize and spread contamination and accelerate slumping at OU 1 Experience with installation of the french drain system has indicated that slumping is a serious concern for unsaturated conditions, and would be more serious for the highly saturated conditions that would be required to implement bioremediation

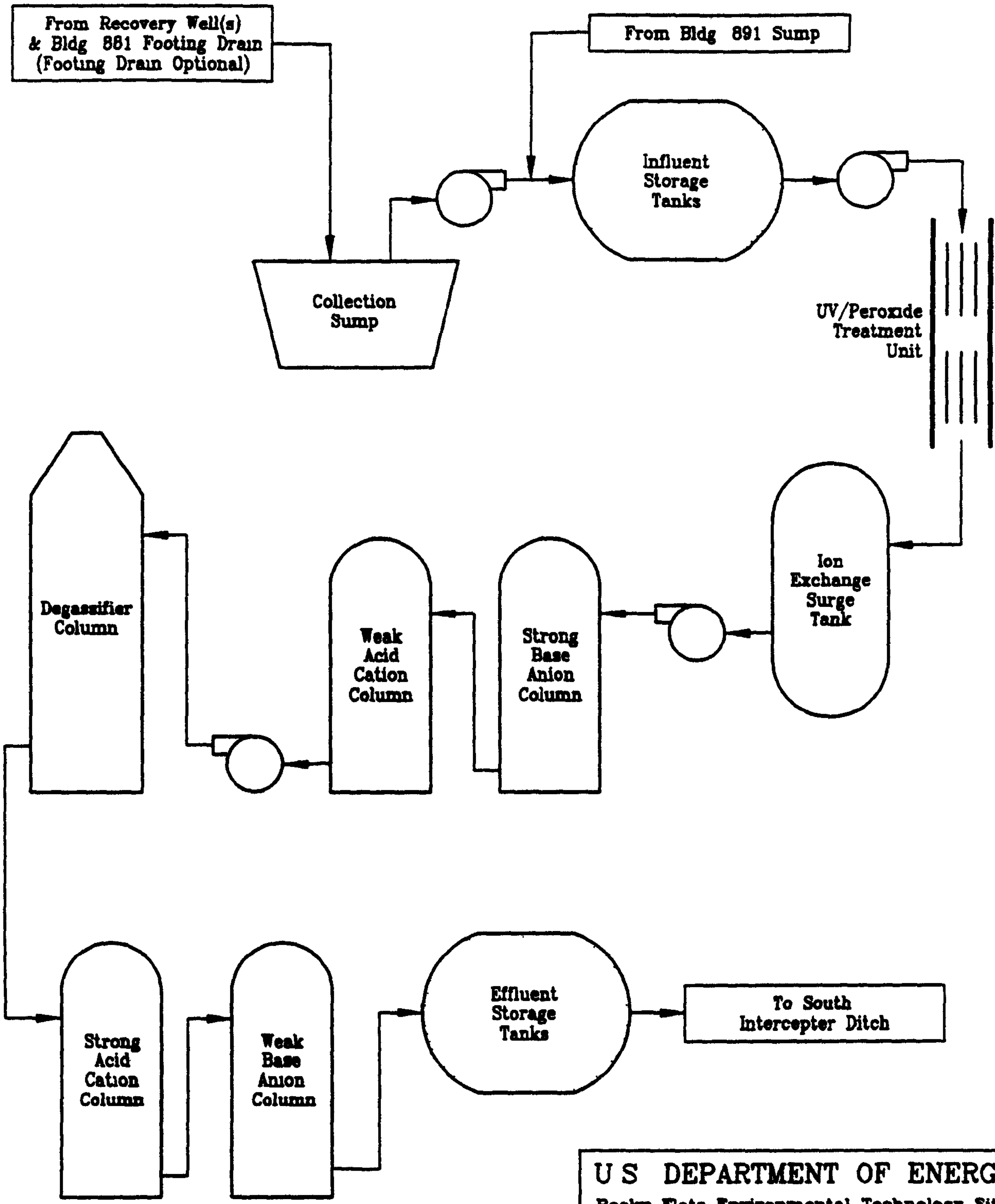
## 2 7 Existing IM/IRA Treatment System

The existing Building 891 water treatment system ($UV/H_2O_2$ and ion exchange) will be essential for proposed remedial action alternatives for OU 1 and other operable units that require aboveground groundwater treatment The system constitutes a comprehensive process treatment train for treating water contaminated with organic and inorganic (including radionuclide) contaminants (see Figure 2 2) The system consists of a collection and pumping system to supply the treatment facility an influent storage and transfer system separate treatment systems for organic and inorganics contaminants, and an effluent storage and discharge system The system is designed for a 30 gpm flow rate capacity and has equalization tanks to normalize treatment rates

The french drain collection and pumping system includes the recovery well pump located in IHSS 119 1 two french drain sump pumps and the Building 891 sump pumps which may be discontinued under a proposed modification These pumps are normally controlled by level switches in the well or sump that determine whether the pumps operate The collection system connects to the influent transfer system, which includes two influent equalization tanks and two influent transfer pumps The influent transfer pumps supply water from the influent equalization tanks to a $UV/H_2O_2$ treatment unit at a constant rate The $UV/H_2O_2$ unit is designed to destroy organic contaminants in the influent stream

Treatment efficiency depends on flow rate (residence time), $H_2O_2$ concentration and UV wavelength intensity The system has a design throughput of 30 gpm or 14 400 gallons per day (gpd) with an 8-hour operating shift It uses 50 mg/$\ell$ of $H_2O_2$, with sixteen 15-kW UV lamps providing an equivalent power of 240 kW for breaking down organics

When the water leaves the $UV/H_2O_2$ system it enters the ion exchange system, which consists of the ion exchange surge tank four columns containing beds of ion exchange resins and a degassing tower The ion exchange system processes the water in the following sequence

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Conceptual View of Existing UV/Peroxide Treatment System

Figure 2-2

OU1-PTS DWG

1 The water enters the ion exchange surge tank and is pumped at a constant rate into the first ion exchange column This column contains 28 cubic feet of Ionac A 440 a strong base anion resin for removing uranium

2 The water then flows directly to the second column which contains 32 cubic feet of Ionac CC a weak acid cation resin for removing heavy metals

3 The water then enters the degassing tower to allow carbon dioxide and other gases produced during the $UV/H_2O_2$ process to escape Excessive gas content in the ion exchange columns could cause short circuiting of the resins thereby reducing the efficiency of the system

4 The water is then pumped to the third ion exchange column which contains 56 cubic feet of Ionac C 240H a strong acid resin for removing hardness and metals

5 The water then enters the fourth and final column which contains 56 cubic feet of Ionac AFP 329 a weak base anion resin, for removing anions

6 The water which is now treated, is stored in one of three effluent storage tanks and discharged by gravity feed

In terms of proposed remedial action alternatives the system can handle most contaminants identified in OU 1 groundwater at their current concentrations and the proposed treatment rates If unusually high concentrations of specific contaminants are encountered the system may require modification to maintain effluent requirements If other operable units require the use of this system the system may require modifications to remove contaminants if their concentrations differ significantly from OU 1

# 3 0 DEVELOPMENT AND SCREENING OF REMEDIAL ACTION ALTERNATIVES

This section presents the alternatives that were assembled for remediating the groundwater medium at OU 1 These alternatives were assembled using the technologies identified both in Section 2 0 and evaluated in detail in TM #11 Appendix A summarizes the evaluation of technologies and process options TM #11 also contains the screening of remedial action alternatives the results of which led to the alternatives presented in this section Note that the alternatives presented herein differ slightly from those discussed in TM #11 Alterations were made where necessary in response to agency comments However the conceptual approaches originally proposed are still maintained in this document In general most of the material presented in TM #11 is presented herein The only alternative screened from further consideration in TM #11 involved capping of the site Capping would require institutional controls to maintain the integrity of the cap, but would not provide any additional protection beyond the controls themselves

An integral component of most of the alternatives presented in this section involves utilizing the existing Building 891 water treatment system This system may also be used for treating contaminated water from other areas of the RFETS If required, the system could be modified to treat higher concentrations of specific contaminants however currently the system is capable of treating the COCs identified at OU-1 at their current concentrations Decommissioning of the french drain may be appropriate once remedial actions are completed This subject is discussed further under each alternative

## 3 1 <u>Development of Remedial Action Alternatives</u>

Remedial action alternatives were developed by combining process options which were selected as being representative options based on the results of the evaluation of process options and technologies Process options were combined in such a way as to permit alternatives to be developed that would range from treatment alternatives that eliminate or minimize the need for long term management to limited or no action alternatives This range of alternatives includes containment options that involve little or no treatment but achieve RAOs by preventing exposures or by reducing the mobility of contaminants The no action alternative was developed to provide a baseline alternative against which other alternatives could be compared In all cases the alternatives were developed with the goal of achieving the groundwater RAO presented in Section 2 0 by combining appropriate GRAs to form site-specific remediation strategies

The alternatives that were developed for remediation of OU 1 are the following

- Alternative 0 No Action
- Alternative 1 Institutional Controls without the French Drain
- Alternative 2 Institutional Controls with the French Drain
- Alternative 3 Modified French Drain with Additional Extraction Wells
- Alternative 4 Groundwater Pumping and Soil Vapor Extraction
- Alternative 5 Groundwater Pumping and SVE with Thermal Enhancement
- Alternative 6 Hot Air Injection with Mechanical Mixing
- Alternative 7 Soil Excavation and Groundwater Removal with Sump Pumps
- Alternative 8 Capping with Institutional Controls

Table 3 1 depicts a summary of the development of remedial action alternatives The table presents the GRAs and process options that were combined to form the various alternatives After developing alternatives for remediation of OU-1 the alternatives were screened on the basis of effectiveness implementability, and cost as described in TM #11 Alternatives that were dropped from further consideration are also indicated in Table 3 1 by shaded areas

## 3 2 Groundwater Remedial Action Alternatives

Groundwater remedial action alternatives were developed that could potentially achieve the RAOs described in Section 2 0 The primary risk pathways that determined which GRAs would be used to develop alternatives were based on the OU 1 BRA, which indicated that ingestion of groundwater and inhalation of vapors rising up through unsaturated soils were the largest concerns The following groundwater alternatives were designed to achieve RAOs by removing and destroying the contaminants in groundwater by restricting access to wells positioned within the boundaries of OU 1 and/or by limiting access to the site completely These alternatives assume that surface soil hotspots would be removed prior to commencing remedial activities and would be put into temporary storage for treatment with similar wastes from another OU or shipped off site for immediate treatment and/or disposal

3 2 1 Alternative 0. No Action

The No Action alternative for groundwater was developed to meet the requirements of the NCP which state that a No Action alternative should be developed regardless of site-specific conditions (EPA 1990a) The alternative provides a baseline against which other alternatives can be compared during the detailed analysis of alternatives The No Action alternative uses the results of the BRA to define what the exposure levels would be to receptors under this alternative, and does not seek to actively remediate any portions of OU 1

This alternative includes monitoring only to determine if any changes occur in contaminant concentrations or in contaminant migration patterns Groundwater monitoring would begin immediately and would take place for as long as institutional controls are active at the site or until it is determined that monitoring is no longer required Wells no longer deemed necessary for monitoring would be abandoned as appropriate

This alternative assumes that the site would eventually be abandoned, and that no remedial actions would be initiated to reduce the risk from groundwater contaminants or to remediate potential residual DNAPL zones believed to be present in the subsurface soils beneath IHSS 119 1 The alternative assumes that the treatment portion of the existing french drain system would be non-operational Groundwater reaching the drain would begin to flow around the drain at a slow rate assuming the existing sumps were not pumped regularly This would result in a saturated region directly upgradient of the drain, and a less saturated region downgradient of the drain however no adverse impacts are expected If desired, the drain could be decommissioned by excavating portions of the impermeable layer downhill from the drain with a standard backhoe to increase its effective permeability For the purposes of detailed analysis it is assumed that the drain would be decommissioned as suggested under this alternative

Since no remedial actions would be conducted under this alternative there is no remediation time frame involved Decommissioning the french drain would be accomplished using RFETS equipment and would require minimal effort This alternative would also not involve any packaging or transportation of waste nor any permitting actions

3 2 2 Alternative 1. Institutional Controls without the French Drain

This alternative is intended to minimize the risk from contaminated groundwater by restricting access to any wells impacted by OU 1 contaminants and by eliminating the possibility of building construction above areas known to be contaminated with VOCs This alternative would attempt to meet RAOs by applying institutional controls to the boundary of the RFETS at Woman Creek

The alternative assumes that the existing french drain system would not be operational as in the No Action alternative Groundwater reaching the drain would flow around the drain at a slow rate assuming the existing sumps were not pumped regularly This would result in a saturated region directly upgradient of the drain and a less saturated region downgradient of the drain however no adverse impacts are expected If desired the drain could be decommissioned by excavating portions at the drain with a standard backhoe to increase its effective permeability For the purposes of detailed analysis it is assumed that the drain would be decommissioned as suggested under this alternative

Groundwater monitoring would be required for this alternative to determine when institutional controls could be discontinued Once acceptable groundwater contaminant concentrations were achieved through natural degradation and dispersion of contaminants, the area would be released from institutional controls Groundwater monitoring would take place for as long as required to meet this criterion Wells no longer deemed necessary for monitoring would be abandoned

This alternative assumes the site would not be abandoned during the institutional control period but that no remedial actions would be taken to actively reduce the contaminant concentrations in groundwater, or to remediate potential residual DNAPL zones believed to be present in the subsurface soils beneath IHSS 119 1

As in the No Action alternative there is no remediation time frame associated with this alternative since the site would not be released until acceptable groundwater concentrations are achieved Decommissioning the french drain would be accomplished using RFETS equipment and would require minimal effort For the purposes of detailed analysis a 30-year institutional control period is assumed for groundwater monitoring

This alternative would not involve any packaging or transportation of waste, nor any permitting actions other than the administrative requirements associated with maintaining the security of the site

### 3 2 3 Alternative 2. Institutional Controls with the French Drain

This alternative is intended to minimize the risk from contaminated groundwater by restricting access to any wells impacted by OU 1 contaminants while continuing to treat groundwater collected by the existing french drain This alternative is similar to Alternative 1 with the exception that the french drain would not be decommissioned This alternative applies to the area south of building 881 and to the IHSS 119 1 source area Dilute concentrations of contaminated groundwater to the east of the operable unit would not be actively remediated by this alternative although institutional controls would prevent unauthorized construction and uses of groundwater in all areas of OU 1 Suspect areas of subsurface soil DNAPL contamination are not addressed under this alternative other than through containment of groundwater

Groundwater monitoring would take place for as long as required to verify that contaminant concentrations in groundwater have been permanently reduced below appropriate limits For this alternative the existing extraction well located in IHSS 119 1 would continue to be used as a groundwater collection source  Wells no longer deemed necessary for monitoring would be abandoned as appropriate

Although remedial actions would be conducted under this alternative in the form of operating the french drain system  there is no remediation time frame defined since the system is currently operational and would continue operating until acceptable contaminant concentrations are achieved  Based on operations to date of the existing french drain system, however  it is reasonable to assume that the slow groundwater collection rate would require its operation for an extensive period of time  Monitoring of groundwater would also begin immediately  This alternative could involve packaging and transportation of spent ion exchange resin

3 2 4  Alternative 3.  Modified French Drain with Additional Extraction Wells

Alternative 3 differs from Alternative 2 in that additional extraction wells would be added to the existing french drain system to enhance its effectiveness  This alternative would seek to provide protection of human health and the environment by removing contaminants from all areas of OU 1 groundwater, and by entirely containing groundwater upgradient of the french drain  As in Alternative 2  suspect areas of subsurface soil DNAPL contamination are not addressed under this alternative other than through containment of groundwater

Wells could be added to the southeastern corner of the operable unit to capture any contaminated groundwater potentially flowing around the french drain, to the IHSS 119 1 source area to assist the existing recovery well, and/or in front of the french drain in any suspected sandstone lenses which could form conduits for groundwater transport beneath the drain  These wells could also be used to monitor COC concentrations in the area  In addition, under this alternative wells could be installed in the area south of Building 881 to enhance the recovery of contaminated groundwater in that area  Figure 3-1 shows possible locations of additional extraction wells  These locations are identified solely for defining the conceptual approach suggested for this alternative  Prior to designating exact locations, a thorough review of the impact the french drain is having at the site, potentially including computer modeling  is necessary

Modifications required to the french drain itself would be to eliminate the flow of the footing drain water from the 881 Building to limit the amount of clean water that is sent through the treatment system

Groundwater recovered from the extraction wells would be routed to the french drain sump then transferred to the influent storage tanks of the existing Building 891 water treatment system Recovered groundwater would therefore have to be pumped at a flow rate compatible with the system s 30 gpm capacity This system was constructed to treat groundwater from the 881 Hillside area to achieve the treatment goals presented in the *Systems Operation and Optimization Test Report* (DOE 1992)

The institutional control of groundwater monitoring would be employed to determine when contaminant concentrations fall below acceptable levels (assumed to be 30 years for costing purposes in the detailed analysis of alternatives) The existing french drain system would provide containment of contaminants during remedial actions while also assisting in the collection of groundwater After remedial actions are completed however the drain could be left in place or decommissioned If left in place groundwater reaching the drain would begin to flow around the drain at a slow rate, assuming the existing sumps were not pumped regularly This would result in a saturated region directly upgradient of the drain and a less saturated region downgradient of the drain however no adverse impacts are expected If desired the drain could be decommissioned by excavating portions at the drain with a standard backhoe to increase its effective permeability For the purposes of detailed analysis it is assumed that the drain would be decommissioned as suggested under this alternative

Four to six additional extraction wells would be installed under this alternative and would require approximately six inch diameter casing Because of the low hydraulic conductivity and small saturated thickness of 881 Hillside colluvial materials cyclical operation with pumping rates below one gpm per well would be required to remove groundwater

Computer simulations of domestic water production capabilities from OU 1 were completed and presented in the report entitled *OU 1 Domestic Water Supply Simulations* (EG&G 1992) and are included in Appendix F of this report Results of these simulations showed that with a hydraulic conductivity of 1 x $10^{-4}$ cm/sec pumping rates exceeding 0 14 gpm would desaturate the modeled well cell in under 365 days The model assumed a 12 hour pumping period With a hydraulic conductivity of 1 x $10^{-5}$ cm/sec pumping rates exceeding 0 013 gpm would desaturate the modeled well cell in under 365 days Based on the Phase III RFI/RI report the hydraulic conductivity at IHSS 119 1 and the area south of IHSS 119 2 is estimated at 9 4 X $10^{5}$ ft/min while the area south of Building 881 has an estimated hydraulic conductivity of 1 5 X $10^{-5}$ ft/min These hydraulic conductivities suggest that extremely low pumping rates would be required to remove contaminated groundwater without desaturating the modeled well cells

The overall remediation time frame based on using this alternative would be extensive considering the low groundwater pumping rates achievable at OU 1 The potential exists for an extensive extraction time required for removal of residual DNAPLs potentially present in saturated soils Recent EPA guidance recognizes that complete remediation of DNAPL contaminants using conventional groundwater extraction techniques is not technically practicable (EPA 1992b) Again, for the purposes of detailed analysis it is assumed that this alternative would be implemented for at least 30 years

3 2 5 <u>Alternative 4. Groundwater Pumping and Soil Vapor Extraction (SVE)</u>

This alternative seeks to achieve groundwater RAOs by dewatering the IHSS 119 1 source area using conventional pumping techniques, and then following this action with implementation of a localized SVE system The combined technologies proposed under this alternative are considered emerging technologies which may be more effective than when applied individually In general this alternative targets only the IHSS 119 1 source area although additional vapor extraction wells could be installed in other areas to treat suspected DNAPL sources

SVE would assist the vaporization and subsequent recovery of contaminants present in the saturated soils unsaturated soils and groundwater at OU 1 The technology targets contaminants that have partitioned either to the aqueous phase in the subsurface adsorbed onto subsurface soils exist as pools of DNAPL or occupy soil pore spaces as vapor As discussed above groundwater residing in shallow pools throughout IHSS 119 1 would be extracted via the existing well the existing french drain and one or two additional recovery wells Collected groundwater would be treated by the existing Building 891 water treatment system or another appropriate facility with any modifications required to treat unusually high contaminant concentrations if encountered These same areas would be subjected to SVE once desaturated to enhance the removal of any residual contaminants

In general soil vapor extraction is an in situ physical treatment technology that has been used primarily to remediate soil and groundwater contaminated with VOCs A typical SVE system consists of either a single or if necessary a network of vapor extraction wells screened at depths consistent with the contaminated soils If multiple vapor extraction wells are used they are usually joined together by a common header pipe Makeup or clean air replacing the contaminated soil gas removed through SVE enters the soil either passively via the ground surface and/or inlet wells or actively via air injection wells Also the application of surface seals may redirect makeup air to desired treatment zones

The basic principle behind SVE involves inducing vapor flow through the unsaturated zone towards an extraction well by applying a vacuum to that well Contaminants volatilized from the soil matrix and those that are already in the vapor phase are swept by the carrier gas flow (primarily air) to the extraction well(s) The carrier gas also tends to increase the volatilization of any aqueous phase or free phase DNAPL contaminants in the vicinity Many complex processes occur on the microscale, however there are three main factors that control the performance of an SVE operation (a) the vapor flow rate through the unsaturated zone (b) the flow path of carrier vapors relative to the location of the contaminants and (c) the chemical composition of the contaminants (Johnson et al 1989)

To successfully design and operate an SVE system site geology and contaminant properties must be considered Site geology can have a significant influence on a vapor extraction well s radius of influence Geological factors include depth to groundwater subsurface soil/rock type and subsurface permeability which must be great enough to allow carrier vapors to strip VOCs from the subsurface matrix and carry them to an extraction well Soil vapor extraction performance is also dependent on the characteristics of the contaminants targeted for extraction A compound is a likely candidate for SVE if it has a vapor pressure of 1 0 mm or more of mercury at 20°C and a dimensionless Henry s Law constant greater than 0 01 (Danko 1989) Table 3 2 presents these values for the COCs under consideration at OU 1 as well as other general physical and chemical data The data shown indicate that all of the COCs under consideration are amenable to recovery by SVE A cross sectional view of the proposed conceptual configuration of an SVE system is presented in Figure 3 2

For this alternative it is assumed that approximately 10 to 30 vapor extraction wells would be installed in IHSS 119 1 and in other areas if deemed appropriate A detailed soil gas survey would have to be conducted prior to installing these wells in order to pinpoint exact well locations Wells would be installed to a depth of approximately 20 feet and would be 4 to 6 inches in diameter These wells would be operated cyclically to enhance recovery and would be used in combination with a granular activated carbon (GAC) unit to treat extracted vapors This unit would most likely require a National Emission Standards for Hazardous Air Pollutants (NESHAPs) permit to operate however this would not present any unusual administrative constraints

The remediation time frame associated with this alternative is assumed to be approximately five years Groundwater monitoring would continue once the alternative was implemented to ensure that all residual phase DNAPL zones are remediated Monitoring would be active for 30 years after remediation unless it was determined that acceptable contaminant concentrations have been reached

Also once the SVE system was decommissioned, operation of the french drain would be suspended In general groundwater reaching the drain would flow around the drain at a slow

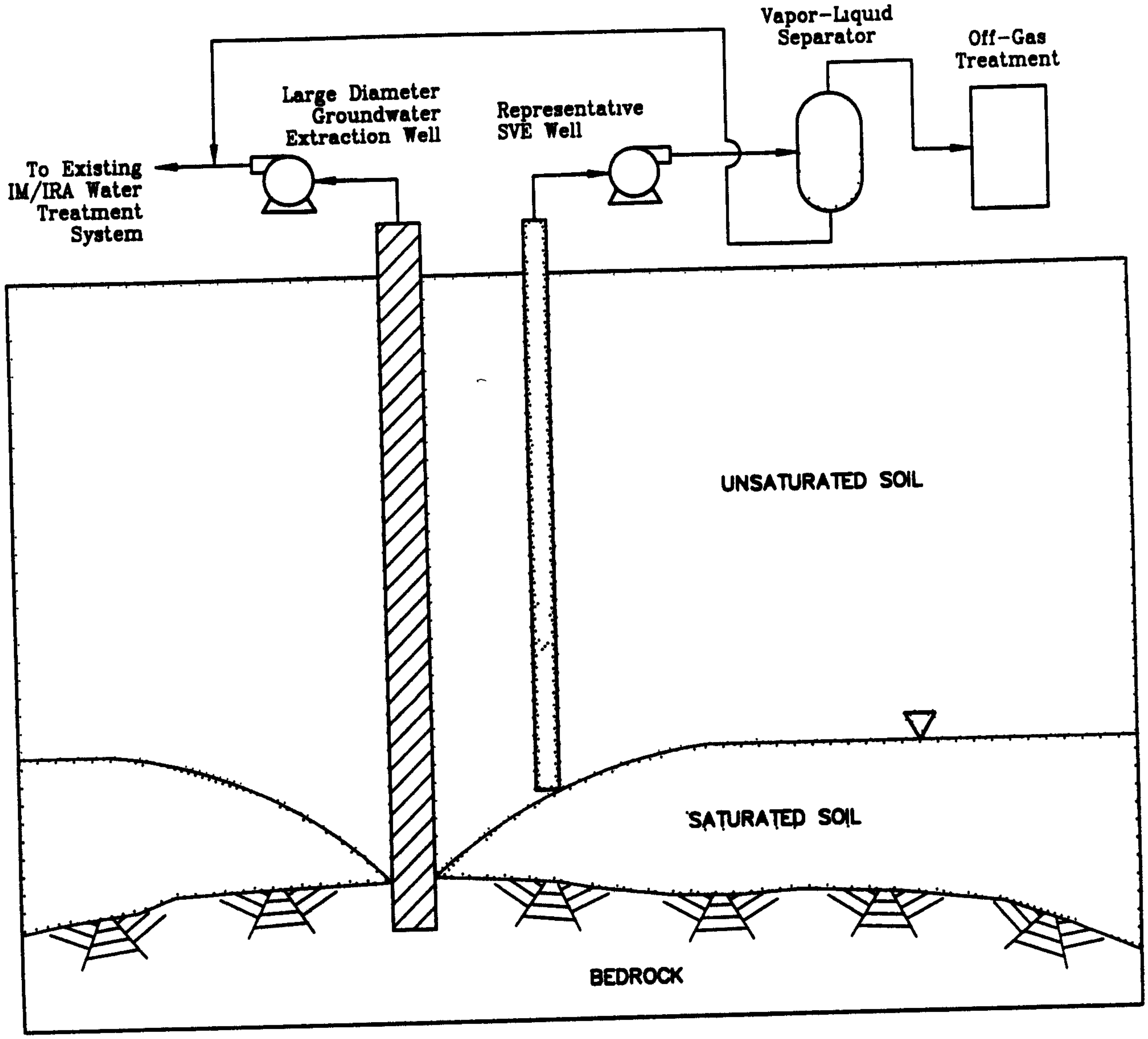
## Table 3-2
## Physical and Chemical Properties of the Primary VOCs in Groundwater

| Chemical | Formula[a] | Molecular Weight[a] | Specific Gravity[b] | Boiling Point ( C)[b] | Aqueous Solubility (mg/ℓ)[a] | Vapor Pressure (mm Hg) | Henry s Law Constant (Dimensionless) |
|---|---|---|---|---|---|---|---|
| Carbon Tetrachloride | $CCl_4$ | 153 82 | 1 59 | 76 5 | 757 | 90 | 1 001 |
| 1 1 Dichloroethene | $C_2H_2Cl_2$ | 96 94 | 1 22 | 37 0 | 5 500 | 182 | 0 179 |
| Tetrachloroethene | $C_2Cl_4$ | 165 83 | 1 62 | 121 | 150 | 17 8 | 1 076 |
| 1 1 1 Trichloroethane | $C_2H_3Cl_3$ | 133 39 | 1 34 | 75 1 | 950 | 100 | 0 170 |

[a] from ***Hazardous Waste Management*** LaGrega Buckingham and Evans McGraw Hill New York 1994

[b] from ***Selecting Process Equipment, vol 1*** Woods McMaster University Canada 1990

[c] from ***Hazardous Waste Management*** ibid at 20 C




Not To Scale

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**Conceptual View of SVE System Cross Section**

**Figure 3-2**

OU1-CS1 DWG

rate assuming the existing sumps were not pumped regularly This would result in a saturated region directly upgradient of the drain and a less saturated region downgradient of the drain however no adverse impacts are expected If desired the drain could be decommissioned by excavating portions at the drain with a standard backhoe to increase its effective permeability For the purposes of detailed analysis it is assumed that the drain would be decommissioned as suggested under this alternative

3 2 6 Alternative 5. Groundwater Pumping and SVE with Thermal Enhancement

This alternative seeks to enhance the vaporization and subsequent recovery of contaminants present in the subsurface soils and groundwater at OU 1 As with the previous alternative this alternative targets contaminants that have partitioned to aqueous, and vapor phases or are residuals in the subsurface This alternative considers technologies that enhance vaporization through the elevation of subsurface temperature in areas where target contaminants are concentrated Groundwater residing in shallow pools throughout IHSS 119 1 would be extracted via existing wells the existing french drain, and one or two new recovery wells Collected groundwater would be treated by the existing Building 891 water treatment system These same areas would be subjected to thermal enhancement techniques once desaturated to enhance the removal of any residual contaminants Thermal enhancement is expected to be especially well suited for sites with tight formations such as is the case with OU 1 and is considered an emerging technology by EPA

As soil gas contaminated with contaminant vapors is recovered through a standard vapor extraction system and replaced with clean soil gas aqueous phase, DNAPL phase and adsorbed contaminants vaporize until they return to equilibrium saturation levels in the clean soil gas thus increasing both the vaporization rate of these contaminants and the equilibrium air saturation levels by temperature elevation subsequently increases recovery by vapor extraction Although increased vaporization rate and increased equilibrium saturation levels would increase the effectiveness of the vapor extraction system the primary increase in total contaminant recovery would result from an increase in the number of open pore spaces available for vapor transport Any vaporization enhancement techniques used with vapor extraction would decrease the moisture content of the surrounding media Pore spaces that were initially filled with water would be opened once the water was vaporized and driven off The open pore spaces would allow for a greater diffusion rate of vapor phase contaminants thereby increasing their extraction rate and possibly the radius of influence of a vapor extraction system

This alternative considers two viable treatment technologies that can effect an increase in subsurface soil temperatures — radio frequency heating and electrical resistance (ohmic) heating Both technologies are discussed below although for the purposes of detailed analysis radio frequency heating is analyzed further, whereas ohmic heating is merely assumed to be potentially applicable at OU 1 and is not included in the detailed analysis of alternatives

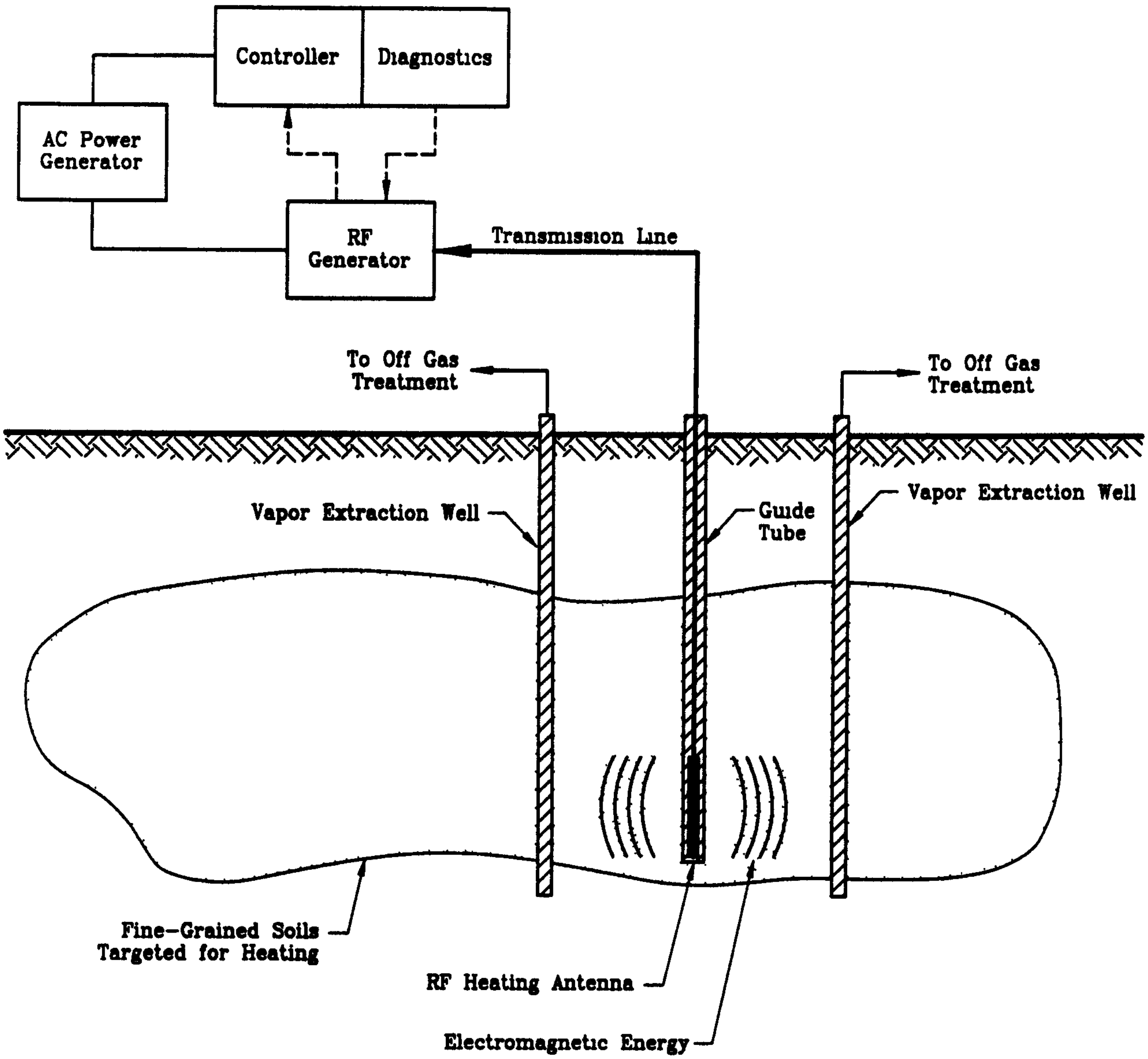
Radio Frequency Heating

Radio frequency (RF) heating was selected as one of the two representative process options to effect an elevation in temperature of the subsurface materials at OU-1 that are contaminated with those contaminants that are VOCs RF heating is an innovative in situ technology for volatilizing organic constituents in soil and water as well as vaporizing pore space moisture The technology is desirable since additional chemicals are not introduced into the subsurface and no special arrangement (e g grids) are necessary as in conventional ohmic heating

The in situ RF heating process requires minimal intrusion using 3 to 6-inch diameter boreholes containing strategically placed antennae in the desired treatment area Through a combined mechanism of ohmic and dielectric heating the temperature in the media is raised and the volatile and semivolatile organic constituents are volatilized (Kasevich 1992) Volatilized organics are then collected with the vapor extraction system and subjected to further treatment RF heating is expected to supplement vapor extraction in a manner that allows for quicker recovery of VOCs from certain areas of the subsurface Specifically heating VOC source areas can expedite VOC recovery in the vapor form (i e , hotspots are likely to contain aqueous DNAPL and adsorbed phase VOCs which would be driven to vapor under elevated temperature conditions) Figure 3 3 illustrates a simple application of RF heating combined with vapor extraction for this alternative

The dielectric loss of a material (i e the amount of energy a material dissipates as heat when placed in a varying electric field) contributes to the heating of the contaminated media An indicator of a material s ability to successfully absorb electromagnetic energy is its dielectric constant Most soils have suitable dielectric constants that allow for effective treatment Water and/or soil moisture is vaporized by RF energy however steam is transparent to RF energy and does not continue to absorb radiation energy While the steam may become superheated this occurs only by energy conduction from the solid media and not from direct electromagnetic energy absorption The steam in turn serves to heat surrounding materials, enhancing additional vaporization Thus, water and/or soil moisture does not present a hindrance to the treatment process Fractures and voids within the contaminated matrix also do not present treatment problems since thermal conduction is not the primary heat transfer mechanism Densely packed soils are well suited to this treatment as are other consolidated geologic materials A variety of heating profiles can be generated by manipulating the subsurface placement of RF antennae their operating frequencies, and the phase output of the different antennae Virtually uniform heating within a specified volume can be achieved with minimal heating of surrounding material using a properly designed configuration Thus localized treatment can be attained with proper design

RF heating has been shown to be capable of increasing soil temperature to approximately 500°F This temperature would be great enough to volatilize both sorbed and potentially dissolved phase contaminants (e g aqueous phase) in the subsurface materials as well as drive off any moisture in nearby pore spaces The temperature of the subsurface medium would be raised gradually therefore vapor extraction wells would be able to extract vapor as it is generated The heating and resulting steam/vapor generation rate could be controlled so that the capacity of the vapor recovery system would not be exceeded Such control would prevent the spread of contamination by steam plume expansion Also RF heating would only be implemented in the vicinity of a vapor extraction well Placement of an RF heating antennae in this manner would provide assurance that RF heating would not lead to a spread of contamination A vapor




Note Figure represents information provided in part by KAI Technologies Inc

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**Conceptual View of Radio Frequency Heating System**

**Figure 3-3**

OU1-CS2 DWG

recovery system supplemented with RF heating would likely require additional air drying capacity since it is expected that the RF heating system would lead to the extraction of a greater amount of soil moisture than conventional vapor extraction

The primary piece of equipment of this alternative is the applicator antenna which is placed in a borehole This antenna is generally a flexible component of varying length that radiates electromagnetic energy in the form of radio frequency waves The energy originates from a generator at the surface and is transmitted to the antenna via a metal coaxial cable Standard drilling equipment can be used to complete a borehole The borehole is generally cased with fiberglass or a similar material that is transparent to electromagnetic radiation The antenna can be placed in vertical or horizontal boreholes Also several antennae may be used concurrently in various areas with elevated contaminant concentrations

Locations of RF antennae and vapor extraction wells for cleanup of the volatile subsurface contaminants at OU 1 are contingent on detailed design through which the optimum system design would be defined, however, it is assumed under this alternative that RF heating antennae would be installed in vapor extraction wells near the vapor extraction wells being operated The number of vapor extraction wells required would range from 10 to 30 depending on saturation levels The spacing between boreholes can range depending on the RF heating frequency depth interval of heated volume and properties of the materials heated An array of multiple boreholes can provide uniform heating of a given subsurface volume Control devices monitor performance of the RF generator and adjust the outputs to optimize system performance Soil gas monitoring wells must be in place in the vicinity of the RF heating antennae These wells are necessary to monitor for potential increased migration of contaminant outside of the radius of influence of the vapor extraction well(s)

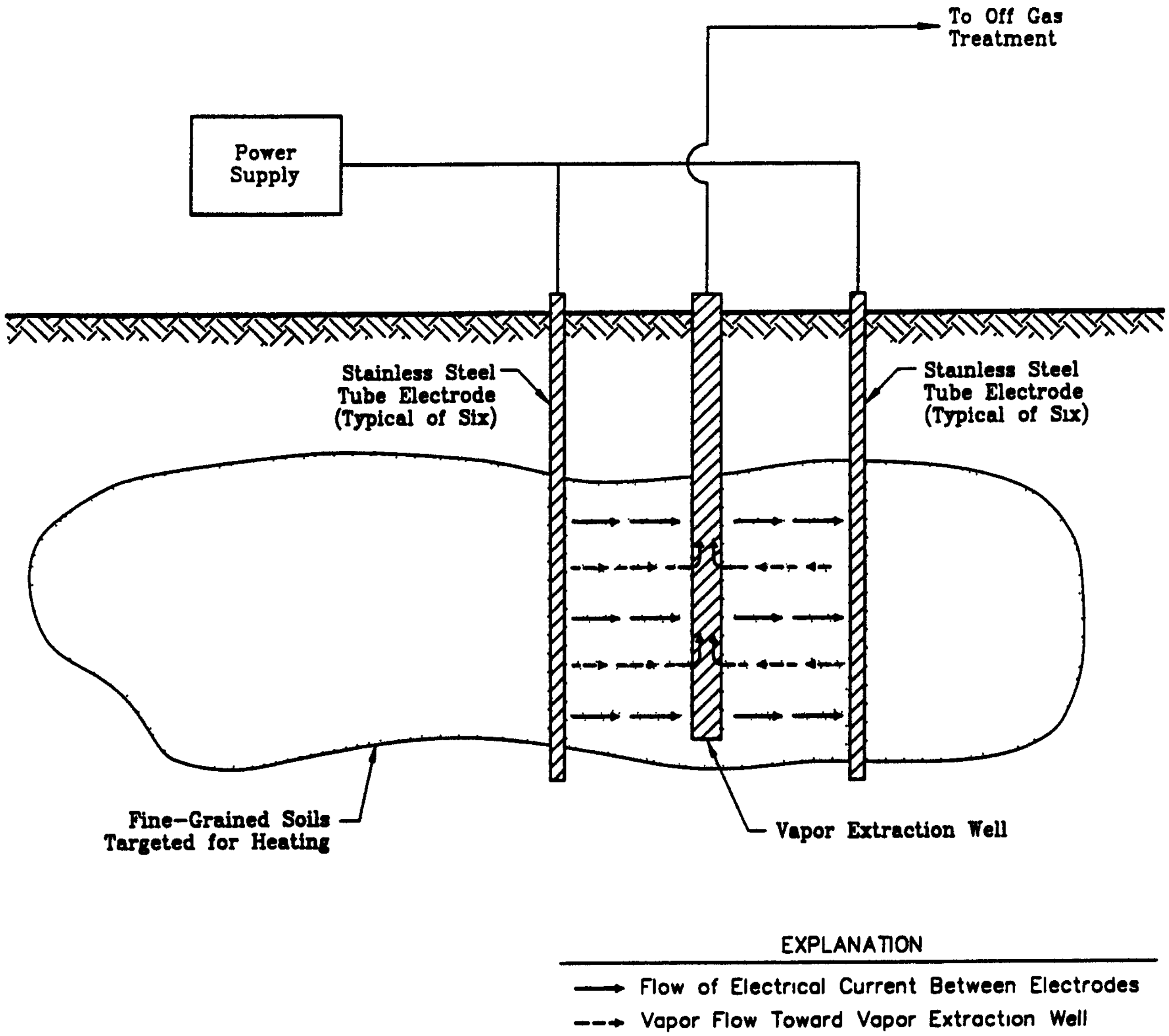
Support equipment for RF heating can be housed in one trailer A portable power supply such as a diesel motor generator, may provide the necessary three phase power for the RF antennae All transmission lines connecting support equipment to the RF antennae are commercially available

Ohmic Heating

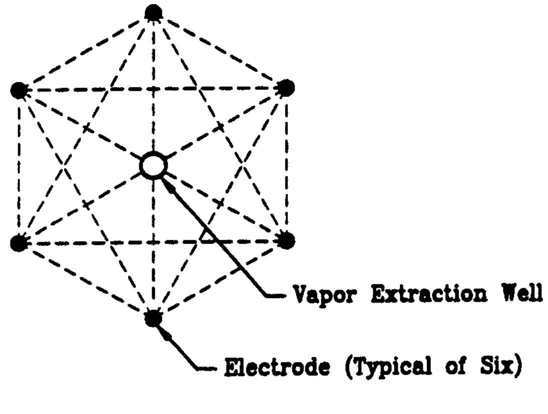
Ohmic heating was also selected as one of the two representative process options to effect an elevation in temperature of the subsurface materials at OU 1 that are contaminated with volatile contaminants This technology is considered an emerging technology which is currently being examined under the Operable Unit 2 (OU 2) treatability study program Like RF heating ohmic resistance heating is an innovative in situ technology for enhancing the performance of soil vapor extraction by volatilizing organic constituents in soils and groundwater and by vaporizing pore space moisture Unlike RF heating however ohmic resistance heating results from the transmission of an electrical current through the media targeted for cleanup As such a prerequisite for ohmic heating is that the media must be able to conduct an electrical current Ohmic heating requires the placement of a grid of electrodes and sometimes the addition of water in the area targeted for remediation The process requires only minimal intrusion and has most often been implemented using six electrodes installed in a hexagonal pattern to the depth of the contaminants, with a vapor extraction well placed in the center of the pattern as shown in Figure 3-4 (Aines et al)

Six or three phase power can be used to supply current to the installed electrodes There is some benefit with six phase power in that a more uniform heating pattern can be realized in the area being treated (Buettner et al) However the increased uniformity comes at the expense of needing additional equipment to split normal three phase power into six phase Electrodes are usually constructed of stainless steel tubing, which can also serve as passive air inlets

The principle of ohmic heating is simple Basically electrical currents are made to flow between electrodes placed in a contaminated region causing resistance heating (much the same way that passing an electrical current through an oven heating element generates resistance heating) Current flow through subsurface materials tends to be greatest in fine-grained soils such as silts and clays These types of soils are generally less permeable than sands and gravel thus heating the clays and silts can drive off contaminants contained therein that are not easily accessible with conventional soil vapor extraction Once the volatile contaminants are driven




Plan View of Grid Arrangement

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**Conceptual View of Electrical Resistance Heating System**

**Figure 3-4**

OU1-CS3 DWG

out of the less permeable clays and silts into the more permeable sands and gravel they are more susceptible to recovery by vapor extraction As with RF heating soil moisture can be heated with ohmic heating to generate steam Steam can provide additional stripping of adsorbed contaminants Also the removal of soil moisture can increase the air flow permeability of the soil being treated thus enhancing the capability of vapor extraction to remove contaminants (but lessening the ability to continue heating the subsurface with electrical current)

The primary pieces of equipment needed to support ohmic heating include stainless steel piping (for electrodes) a 60 Hz power supply an optional six phase transformer thermocouples for monitoring subsurface temperature and a vapor recovery/treatment system Electrode grids may be placed at various locations targeted for treatment Extracted vapors from multiple locations may be directed to a central treatment location or to individual treatment units

The location of the electrode grid(s) and vapor extraction well(s) for cleanup of the volatile subsurface contaminants at OU 1 are contingent on treatability test results in which the optimum system design would be defined, however, for this alternative it was assumed that one grid would be installed at IHSS 119 1 This grid would have six electrodes inserted to approximately 20 feet below the surface in a hexagonal arrangement making up a circle with a diameter of approximately 20 feet Additional grids would be required to remediate the entire site As previously discussed the conceptual approach presented for RF heating is carried forward for detailed analysis The information presented here on ohmic heating may be beneficial if it is selected as the preferred technology prior to implementation of any remedial actions at OU 1

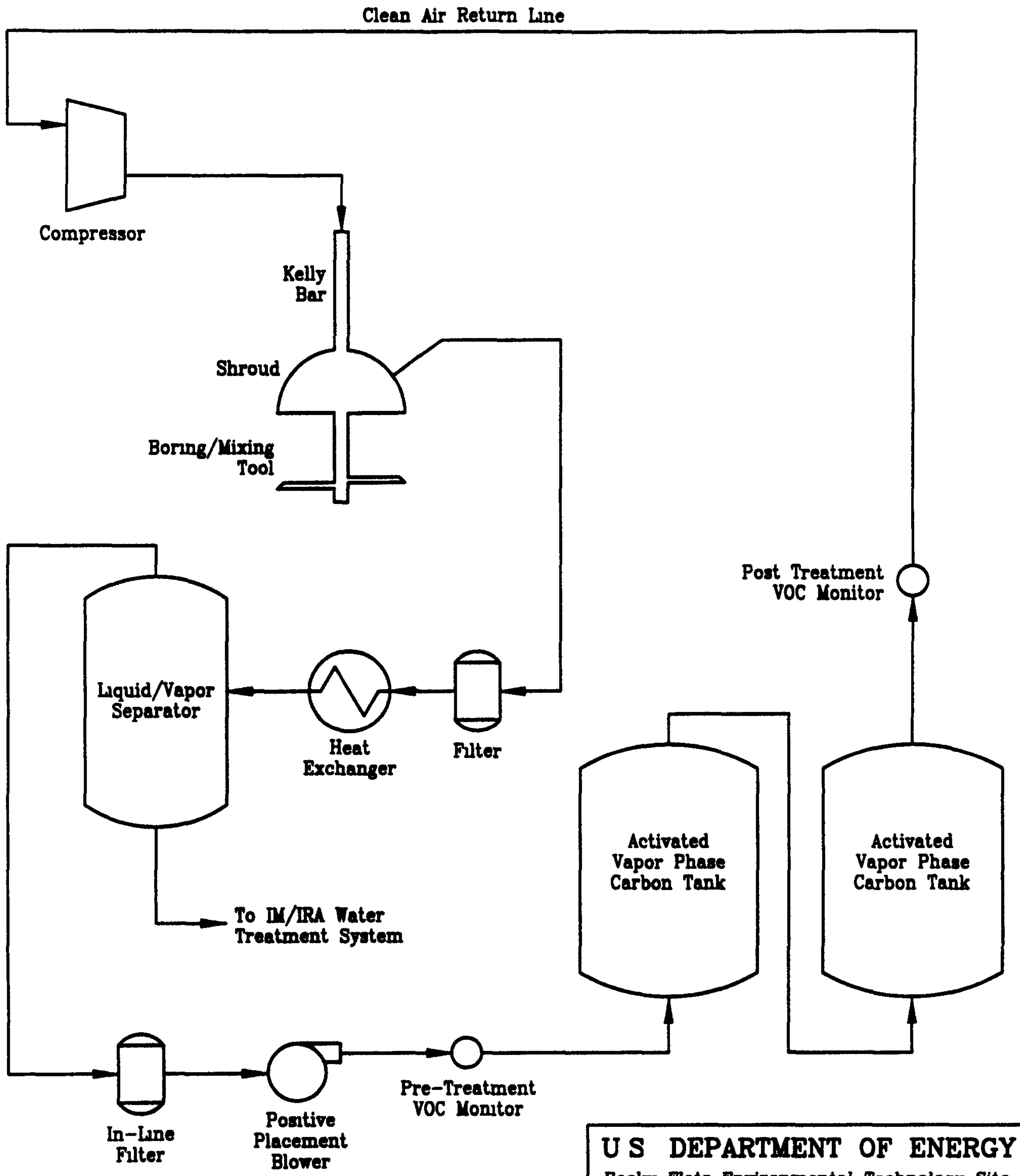
Implementation of either technology would still require groundwater monitoring to ensure that residual DNAPL sources have in fact been remediated In addition, operation of the french drain would be discontinued after implementation of the alternative unless the system was utilized for another operable unit Groundwater reaching the drain would continue to flow around and beneath the drain albeit at a much slower rate than prior to its installation assuming the existing sumps were not pumped regularly This would result in a saturated region directly upgradient of the drain and a less saturated region downgradient of the drain however no adverse impacts are expected If desired the drain could be decommissioned by excavating portions at the drain with a standard backhoe to increase its effective permeability For the purposes of detailed analysis it is assumed that the drain would be decommissioned as suggested under this alternative

This alternative would require a remediation time frame of approximately three years NESHAPs permits would be required for any other gas treatment systems and groundwater monitoring is assumed to be present for 30 years after remediation This would be required to verify that all residual sources of DNAPLs in the subsurface have been remediated

3 2 7 Alternative 6. Hot Air Injection with Mechanical Mixing

This alternative would use groundwater extraction and hot air enhanced vapor extraction with mechanical mixing to enhance recovery of contaminants present in the subsurface at IHSS 119 1 This technology is considered innovative and would have to be tested at OU 1 prior to full scale operation Such a technology would target contaminants that have partitioned to the aqueous phase in the subsurface those that have adsorbed onto the subsurface soils, those that exists as pools of free phase DNAPL and those that occupy soil pore spaces in the vapor phase To maximize the efficiency of this alternative it is assumed that a detailed soil gas survey would be required to identify potential residual DNAPL sources in the subsurface

This alternative requires the remediation of up to 20 000 cubic yards of soil in IHSS 119 1 by in situ treatment with a mobile treatment system The treatment system selected would use hot air to enhance volatilization of adsorbed and dissolved VOCs while simultaneously increasing contact of the hot air with the VOCs by mechanical mixing (Available groundwater would be extracted from the vicinity prior to treatment ) Heated air is both the primary means of temperature elevation induction and of increasing subsurface vapor flow and recovery The mixing enhances volatilization by increasing desorption surface area and eliminating barriers to contact between the contaminants and the hot air Figure 3 5 presents a conceptual view of the hot air injection system

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**Conceptual View of Hot Air Injection System**

**Figure 3-5**

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OU1-WTS DWG

The primary treatment system in this alternative consists of a caterpillar mounted drill rig with specialized drilling equipment The drill equipment is capable of delivering treatment reagents such as hot air or steam via piping in a hollow drill bit shaft The drill bit has a cutting/mixing blade which can vary in diameter from 4 to 12 feet Groundwater extraction wells would be placed in previously treated soil columns Dewatering of a small area prior to treating the initial soil column would be accomplished via an extraction well drilled with conventional drilling equipment Extracted groundwater would be treated through the existing UV/peroxide treatment system The drill rig can produce up to 350 000 ft lbs of torque, sufficient to provide excellent mixing of subsurface soils as the drill bit descends through the soil column The drill bit also has multiple injection ports for hot air delivery The multiple ports provide uniform delivery of hot air throughout the treatment zone The caterpillar mounted drill rig is moved from one treatment zone to another sequentially until the entire site is remediated The treatment columns or drill shafts are overlapped by 20% to ensure adequate treatment throughout the entire site 4 to 6 columns can be treated per day, depending on site conditions

For volatile compounds such as those at OU 1 a negative pressure shroud is placed over the entire treatment zone to capture off gases for delivery to an onboard off gas treatment system Mats are placed under and around the rig to ensure that contaminants do not reach the atmosphere by surfacing outside the shroud The shroud vacuum is connected to an off gas treatment system A vapor-liquid separator removes entrained liquids for delivery to the Building 891 water treatment system Vapors continue through the off gas treatment system For the contaminants and concentrations at OU 1 vapor phase carbon adsorption is the preferred treatment option Once treated the air is recycled to a compressor and heater and reinjected to the subsurface

Removal of groundwater by pumping will be accomplished by extraction wells placed near the treatment zone to depress the water table and recover contaminated groundwater The wells will be placed in post treated soils due to the ease of placement in these disturbed areas This ensures the recovery of aqueous inorganics present in the groundwater Thus the alternative will address inorganic as well as organic contaminants The recovered groundwater would be pumped to the existing Building 891 water treatment system which is designed to treat all contaminants found in OU 1 groundwater

Although this alternative involves removal of the source of contamination monitoring of groundwater would be required once the remedial action is complete to verify that all residual DNAPL sources have been remediated

It is assumed that after completing this alternative the existing french drain would be decommissioned Groundwater reaching the drain would continue to flow around and beneath the drain albeit at a much slower rate than prior to its installation assuming the existing sumps were not pumped regularly This would result in a saturated region directly upgradient of the drain and a less saturated region downgradient of the drain however no adverse impacts are expected If desired the drain could be decommissioned by excavating portions at the drain with a standard backhoe to increase its effective permeability For the purposes of detailed analysis it is assumed that the drain would be decommissioned as suggested under this alternative

This alternative would require 3 years to implement and would require permits for off gas treatment only (assuming the existing Building 891 water treatment system is currently permitted appropriately) Groundwater monitoring would continue for 30 years or until it is determined that monitoring is no longer required

### 3 2 8 Alternative 7. Soil Excavation and Groundwater Removal with Sump Pumps

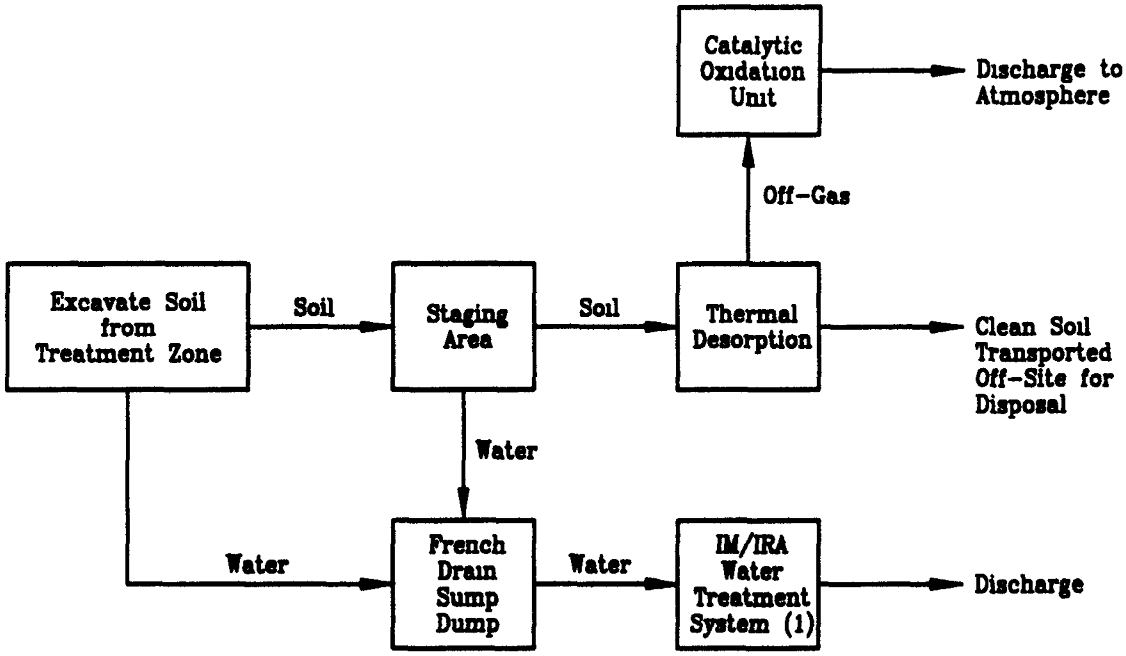
This alternative is intended to reduce or eliminate the risk to a residential receptor at IHSS 119 1 through source removal of contaminated groundwater beneath a discreet portion of the IHSS This alternative differs from the in situ groundwater treatment alternative in that a portion of unsaturated soils at the IHSS would be excavated down to the water table to allow for the removal of localized groundwater contamination This is a worst-case scenario which would enable contaminated water to be located and subsequently removed Such efforts may be required based on the current understanding of the hydrogeologic conditions at OU 1 which suggest complex geology in the area

The volume of groundwater requiring treatment and the amount of soil which would have to be excavated for this alternative were calculated based on the results of the Phase III RFI/RI This alternative would require excavation of approximately 20 000 cubic yards of unsaturated and potentially saturated soils in the southwest corner of IHSS 119 1 (see Figure 2 2) The amount of groundwater collected during the excavation would be approximately 80 000 gallons depending on the seasonal level of the water table This is a rough estimate of the amount of groundwater present under low saturated conditions using the measured porosity of the soils

Excavation would be terminated slightly below the underlying bedrock to ensure that all contaminated groundwater pools are reached The groundwater would be collected using sumps installed within the excavation Standard submersible pumps would be used to direct collected groundwater to the existing french drain sump pumps The groundwater would then be transferred to the Building 891 water treatment system at OU 1 for final treatment and discharge A piping system from the excavation to the OU-1 treatment facility would be required (see Figure 3-6) This would likely be constructed of PVC and buried to a sufficient depth to prevent freezing A control system would also be needed to operate pumps as demand required and to minimize the need for manual oversight and operation

The actual excavation would be accomplished using conventional construction equipment although breathing apparatus may be included as part of the machinery or may be handled separately on an individual basis The excavated soils would be treated on-site using a skid mounted thermal desorption unit and then transported to a licensed facility for disposal

Radiological monitoring would be conducted for the duration of the alternative due to the potential presence of plutonium in the soils Although this alternative involves removal of the source of contamination to groundwater at IHSS 119 1, monitoring of groundwater would still be required once the remedial action is complete to verify that all sources of residual DNAPL




(1) See Figure 2-3

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**Conceptual View of Excavation and Treatment Process**

**Figure 3-6**

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contamination have been remediated Short term monitoring of vapor concentrations in air would also be required during the excavation and prior to its closure

The remediation time frame assumed for this alternative is less than one year Once remediation activities are completed the existing french drain would be decommissioned if appropriate If terms of the drain itself, groundwater reaching the drain would continue to flow around and beneath the drain albeit at a much slower rate than prior to its installation assuming the existing sumps were not pumped regularly This would result in a saturated region directly upgradient of the drain and a less saturated region downgradient of the drain however no adverse impacts are expected If desired the drain could be decommissioned by excavating portions at the drain with a standard backhoe to increase its effective permeability For the purposes of detailed analysis it is assumed that the drain would be decommissioned as suggested under this alternative

# 4 0 DETAILED ANALYSIS OF ALTERNATIVES

This section documents the detailed analysis of the following remedial action alternatives

- Alternative 0 No Action
- Alternative 1 Institutional Controls Without the French Drain
- Alternative 2 Institutional Controls With the French Drain
- Alternative 3 Modified French Drain With Additional Extraction Wells
- Alternative 4 Groundwater Pumping and Soil Vapor Extraction
- Alternative 5 Groundwater Pumping and Soil Vapor Extraction With Thermal Enhancement
- Alternative 6 Steam Injection With Mechanical Mixing
- Alternative 7 Soil Excavation and Groundwater Removal With Sump Pumps

Alternative 8, Capping With Institutional Controls is not included in the detailed analysis of alternatives because it was screened out from further analysis in Section 3

## 4 1 Introduction

This section analyzes the proposed remedial action alternatives using the criteria specified at 40 CFR 300 430 of the NCP Details of the alternatives presented in Section 3 0 are used as the basis for these evaluations The two most important criteria the threshold criteria are statutory requirements that must be satisfied by any alternative in order for it to be eligible for selection The threshold criteria are overall protection of human health and the environment and compliance with ARARs

The five primary balancing criteria of long term effectiveness and permanence, reduction in toxicity mobility and volume short term effectiveness implementability and cost are used to evaluate major performance objectives for alternatives The relative performance of each alternative is evaluated and compared to identify any alternatives that are clearly superior or inferior to the other alternatives under consideration

The two modifying criteria state acceptance and community acceptance evaluate the feasibility of using the preferred alternative in terms of its acceptance by regulatory agencies and the community at large These criteria are not evaluated until after the formal public comment period on the CMS/FS report, and are then addressed in the Corrective Action Decision/Record of Decision (CAD/ROD)

### 4 1 1 Overall Protection of Human Health and the Environment

This criterion addresses the overall protectiveness of the proposed remedy by describing how human health and environmental risks are eliminated, reduced, or controlled through treatment engineering controls or institutional controls This evaluation criterion acts primarily as a final check on the conclusions reached in applying the other primary balancing and threshold criteria In particular this overall assessment of protectiveness draws on the analyses conducted under the compliance with ARARs long term effectiveness and permanence and short term effectiveness criteria The evaluation of overall protectiveness examines whether an alternative results in any unacceptable short term or cross media impacts

### 4 1 2 Compliance with Applicable or Relevant and Appropriate Requirements

The selection of ARARs for a remedial action alternative at a site is governed by the regulations of the NCP [40 CFR 300 400(g)] and EPA s guidance in Office of Solid Waste and Emergency Response (OSWER) Directives such as the *Compliance with Other Laws Manual* (#9234 1) The potential list of ARARs for remedial actions at OU-1 has been presented to the regulatory agencies in TMs #10 and #11 A discussion of the selection of chemical specific ARARs for OU 1 has been presented in subsection 2 3 1 Briefly summarized, ARARs are

- applicable, that is, a requirement that under circumstances other than CERCLA apply to the contaminant action situation or location

  or

- relevant and appropriate This is a requirement that is not normally applicable to the set of circumstances (contaminant activity location or situation) but because the requirement addresses an activity, location or situation similar to the circumstances proposed at the remedial action site and the requirement is well suited to the remedial action at the site it is judged relevant and appropriate It is possible for a requirement to be relevant but not appropriate for site specific circumstances

As remedial action alternatives are developed and screened through the feasibility study process so are the ARARs further analyzed and screened in the CMS/FS process

ARAR Screening Process

Action specific and location specific ARARs previously identified in the early stages of the CMS/FS process were screened again to check the jurisdictional and circumstantial prerequisites Each ARAR was noted as applicable or relevant and appropriate for each alternative at OU 1 The criteria used to evaluate applicable requirements are

- substance or contaminant addressed under statute/regulation
- time period statute/regulation is in effect
- activities/action statute/regulation requires limits or prohibits
- who is subject to statute/regulation
- exemptions under statute/regulation

The criteria used to evaluate relevant and appropriate requirements are

- similarity of substance or contaminant addressed under statute/regulation to situation at OU 1

- similarity of media affected by the requirement under statute/regulation to circumstances at OU 1

- similarity of entities affected by statute/regulation to actions/activities proposed at OU 1

- similarity of the place addressed by statute/regulation and the type of place affected by proposed action at OU 1

- similarity of structures/facility/technology addressed by statute/regulation to structure/facility/technology proposed at OU 1

- any exemptions or variances of a requirement and their availability for circumstances at the OU 1 site

Each specific remedial action alternative is assessed to determine if the proposed action will/can comply with each ARAR or TBC Section 121(d) of CERCLA requires remedial actions to comply with or exceed the ARARs designated at a site This is one of the primary threshold criteria designated in the NCP regulations for choosing a proposed remedial action at a site The results of the ARAR analysis conducted at OU 1 specific to each proposed alternative is presented in Appendix D Key ARARs selected for discussion in the detailed analysis of alternatives listed below where key ARARs are those ARARs judged to be most critical to the implementability of an alternative

- Colorado Primary Drinking Water Standards Articles 1 14 CRS 24-4-104 105 and 25 1 107, 109, 114

- RCRA Regulations - Parts 262 264 265 and 268 and proposed changes to 261

- Colorado Solid Waste Regulations 6 CCR 1007 2 (2 1 15 2 5 5 and 2 5 7)

- Colorado Air Pollution Control Regulations 5 CCR 1001 5 Regulation 7

- Colorado Non game, Endangered or Threatened Species Conservation Act CRS 33-2-101

Compliance with an ARAR can be waived under specific circumstances as designated in CERCLA, as amended [Section 121(d)(4)] and in the NCP regulations Any proposed waivers from compliance with ARARs is presented in the proposed decision document along with the reasons for such contemplated action

Reasons for a waiver include the following

- a State standard has not been consistently applied in similar circumstances
- it is an interim action
- compliance will result in greater risk to human health and the environment than alternative options
- compliance is technically impracticable
- the selected remedial action will attain a standard equivalent to an applicable standard using another approach

Since the State of Colorado is authorized by EPA to implement the RCRA program the RCRA ARARs under the State program are designated as key ARARs Releases and spills at OU 1 occurred prior to the effective date of the RCRA regulations and therefore the RCRA program regulations are designated relevant and appropriate to the substances (spent solvents and contaminated media) and site circumstances at OU 1

Compliance with the RCRA program involving releases of hazardous constituents from solid waste management units (SWMUs) under Subpart F is a relevant and appropriate requirement for all alternatives In addition, the Corrective Action Management Unit (CAMU) Subpart S rule recently adopted by the State (264 552 of 6 CCR 1007 3) is a relevant and appropriate requirement for all alternatives It is a relevant and appropriate requirement because this rule allows remediation wastes to remain in place after closure of the CAMU providing certain requirements are met by the owner The definition of remediation wastes is solid and hazardous wastes and media that contain listed hazardous wastes or which exhibit a hazardous waste characteristic that are managed for the purpose of implementing corrective action requirements "

Requirements of the owner of a CAMU are

1) siting of the CAMU is to be in accordance with the requirements for siting

hazardous waste disposal sites under 6 CCR 1007 2 Part 2 (solid waste minimum standards 2 1) and

2) Subparts B C D and E of Part 264 or 265 are to be met Subpart B is focused on general inspections Subpart C is the preparedness and prevention provisions Subpart D is the contingency plan and Subpart E is the record keeping provisions Subpart E is an administrative requirement and not an ARAR

By designating the unit a CAMU CDPHE will facilitate implementation of a reliable effective protective and cost-effective remedy (criteria of an NCP/CERCLA selection) CDPHE may specify any closure post-closure and any groundwater monitoring or long term maintenance activities as part of the designation (6 CCR 1007 3, Part 264 552(e)) Waste management activities associated with CAMU cannot create unacceptable risks to humans or the environment Since the documentation of the CDPHE designation is required to be made public according to the CAMU rule it is assumed that any designation of the CAMU will appear in the Proposed Remedial Action Plan/Proposed Plan (PRAP/PP) and the CAD/ROD

### 4 1 3 Long Term Effectiveness and Permanence

In addition to the specific statutory requirements discussed in Section 4 1 2 CERCLA guidance emphasizes the preference for treatment to achieve long term protection and permanence for the proposed remedy Criteria for evaluating long term effectiveness and permanence include the following

- persistence, toxicity, and mobility of hazardous substances and their constituents and their tendency to bioaccumulate
- long term uncertainties associated with containment
- long term potential for adverse health effects from human exposures
- long-term cost of monitoring and maintenance
- ease of undertaking future remedial action should the proposed alternative fail

These considerations are focused on the magnitude of residual risk remaining after the response objectives have been met The evaluation of the proposed alternative must include an analysis of the continued potential threat to human health and the environment from untreated waste or treatment residuals remaining at the site after corrective action has been taken This analytical process includes the following elements

- volume and concentration of contaminants in untreated media
- volume and concentration of contaminants in treated residuals
- requirements for five-year site reviews and long term monitoring
- difficulties associated with long term operations and maintenance
- confidence in the adequacy of controls
- availability of equipment used in the alternatives
- habitat value following remedial actions as compared to existing habitat

4 1 4 Reduction of Toxicity, Mobility, or Volume (TMV) Through Treatment

This criterion evaluated the ability of a remedial action alternative to reduce the risks at a site through the destruction of toxic contaminants reduction of the total mass of toxic contaminants reduction in contaminant mobility or reduction in the total volume of contaminated media The NCP states a preference for remedial alternatives that include treatment as a principal element of the remedy over those that do not Specific considerations include the following

- adequacy of the treatment process to address preliminary remediation goals
- specific requirements and limitations of the treatment process
- volume of the contaminated media that are treated
- extent of reduction in TMV
- irreversibility of the treatment
- quantities and toxic characteristics of the treatment residuals or by-products

4 1 5 Short Term Effectiveness

This criterion addresses the period of time during the construction and implementation of the remedy The evaluation covers community protection and site-worker protection during the remediation period as well as any potential adverse environmental impacts that may result from construction and implementation The consideration of environmental impacts during the remediation period also includes an evaluation of the impact of the remedial action on the quality of habitat

### 4 1 6 Implementability

This criterion addresses the technical and administrative feasibility of implementing a remedy including the availability of materials and services needed during its implementation Implementability is particularly important for evaluating the reliability of technologies that are less proven and when evaluating remedies that are dependent on a limited supply of equipment vendors or specialists Specific considerations include the following

- ability to construct and operate the alternative within a 10- to 30-year time frame
- availability of equipment and specialists
- availability and reliability of the components of the alternative
- ability to monitor the effectiveness of the alternative
- demonstrated performance level of the treatment components and equipment
- difficulty in implementing future remedial actions once the alternative is in place

The implementability evaluation also addresses the requirements for coordination with local state and federal offices and agencies to obtain necessary permits

### 4 1 7 Cost

This criterion addresses the evaluation of the capital cost for each alternative as well as the long term operation and maintenance (O&M) expenditures required to sustain it Present worth cost analysis is used to compare expenditures that occur over different time periods By discounting all costs to a common base year the cost of each alternative can be reduced to a single figure for comparative analysis To calculate the present worth of each alternative this report assumes a discount interest rate of 5 percent (as specified in the CMS/FS guidance) and an implementation period of 30 years for long term O&M or the actual implementation period if it is less than 30 years

Cost may play a significant role in differentiating options that appear comparable with respect to long term effectiveness and permanence or when choosing among treatment options that provide similar performance An alternative with a cost that is excessive when compared to overall effectiveness may not be feasible to implement as a final remedy Also, an alternative with a low initial capital cost may be more costly overall when the O&M costs are considered Higher cost may be offset by improved performance or greater long term risk reduction in the comparative analysis of alternatives Ultimately however, the remedial alternative that satisfies the CERCLA requirements in the most cost-effective manner will be selected as the preferred alternative

### 4 1 8 State Acceptance

State acceptance refers to the state or support agency s comments on the appropriateness of the proposed remedy The state s position and key concerns about the preferred alternative should be assessed as early in the process as practicable

### 4 1 9 Community Acceptance

Community acceptance evaluates the issues and concerns raised by the general public in their response to the alternatives described in the CMS/FS report Interested persons or groups in the community may support, have reservations about or oppose some components of the preferred remedial alternative and their concerns may influence the final selection process

## 4 2 Detailed Analysis of Alternatives

Detailed analysis of alternatives is accomplished in this report by evaluating the two threshold and five balancing criteria for each alternative The analysis is conducted at a level of detail that builds on the information presented in Section 3 sufficient to provide an understanding of each alternative and any uncertainties associated with the evaluation Key trade-offs with respect to the criteria are identified for the alternatives According to the CMS/FS guidance the results of the detailed analysis are designed to provide the basis for identifying a preferred alternative for remedial action

Assumptions used in performing the detailed analysis of this CMS/FS include the following

- DNAPLs are potentially present in the subsurface at IHSS 119 1, based on the results of the Phase III RFI/RI report If present it is assumed that they are primarily in residual form and in small quantities
- Groundwater monitoring proposed under each remedial alternative would include sampling and analysis at the french drain, the existing groundwater extraction well and potentially four new monitoring wells at OU 1 The locations would be sampled semiannually and analyzed for both organic and inorganic COCs
- A soil gas survey would be conducted prior to initiating any of the proposed treatment actions to more accurately define the areas at IHSS 119 1 requiring treatment For purposes of the detailed analysis only the previously identified source area is considered

In the comparative analysis a qualitative sensitivity analysis is performed to assess the major assumptions which, if incorrect, could significantly impact the results of the detailed analysis of the alternatives

<u>Groundwater Monitoring</u>

Groundwater monitoring is included as part of each remedial action alternative presented herein For the purposes of the detailed analysis of alternatives it is assumed that six monitoring points would be used for performance monitoring of each alternative Four new wells would be installed, one deep and shallow well cluster downgradient of IHSS 119 1, and possibly two additional wells upgradient of Woman Creek It is suggested that placement of the well cluster be preceded by geological and geophysical support such as photographic lineament analysis, and/or three-dimensional seismic surveys This would enable paleochannels and faulted zones to be clearly identified prior to well placement

Samples would also be collected from the french drain sump and from the existing recovery well Samples would be analyzed for organic and inorganic contaminants and would be collected semiannually Analysis of individual species of inorganic contaminants is also suggested to identify individual metal species which have the potential to bioaccumulate This additional analysis requirement should only be applied occasionally in the sampling program PQLs would be used to determine compliance with CDPHE standards

Groundwater Modeling

To support the detailed analysis of remedial action alternatives, groundwater modeling was performed to predict downgradient contaminant concentrations resulting from suspected sources at IHSS 119 1 Three conceptual models were identified and used to predict future COC concentrations at Woman Creek The no action scenario was used to examine contaminant migration patterns excluding source removal and the existing french drain and extraction well (Alternatives 0 and 1) The french drain institutional control scenario was used to examine contaminant migration patterns with the french drain and extraction well in place (Alternatives 2 and 3) The remediation scenario was used to examine the effect of remediating all of the suspected sources within IHSS 119 1 to MCLs and to predict downgradient concentrations once this goal was achieved (Alternatives 4, 5, 6, and 7)

The groundwater model is described in detail in Appendix B In general the computer simulation code TARGET_2DU (Dames & Moore 1985) was used to simulate contaminant transport in the subsurface TARGET_2DU is a vertically oriented finite difference model that can simulate variably saturated conditions The model will be available for public use late in 1994 This model was selected due to the variability of the saturated zone at OU 1 and because it has been successfully applied at other Superfund sites to support final CADs and RODs

Detailed assumptions and uncertainties associated with the model are included in Appendix B Some of the major assumptions and/or uncertainties that identify conservative points in the model are summarized below

- The model is two dimensional therefore dispersion (spreading) in lateral to the plane of the model is not simulated This causes over prediction of concentrations

- The model does not account for decay of contaminants adsorbed to soil If desorption occurs, then concentrations are conservatively over predicted

- The model does not account for volatilization of organic contaminants It is likely that volatilization is an important process because of high volatilization rates for these chemicals (high Henry s Law constants) and because of the short distance from groundwater to land surface

- The model predicts increasing concentrations at locations like Well 0487 and 4387 where observed concentrations fluctuate around a generally constant average This most likely due to the way in which desorption is simulated and to ignoring the effects of volatilization

In examining the results of the modeling effort, PCE was selected as the indicator chemical for OU 1 The MCL for PCE is $5 \times 10^{-3}$ mg/ℓ PCE concentrations at Woman Creek were at a maximum at the end of the modeled time period for the no action and french drain institutional control conceptual models where they appeared to be approaching an asymptotic value near the maximum concentration predicted Under the remediation conceptual model peak concentrations occurred within the modeled time period The peak concentrations predicted for PCE under each conceptual model (with alternative numbers identified) are listed below along with the year in which the peak concentration was observed

- no action scenarios (0 1) $3\ 60 \times 10^{-3}$ mg/ℓ in 2369

- french drain institutional control scenarios (2 3) $8\ 62 \times 10^{-6}$ mg/ℓ in 2269

- remediation scenarios (4 5 6 and 7) $5\ 84 \times 10^{-4}$ mg/ℓ in 2152 (30-year average at peak) with $5\ 94 \times 10^{-4}$ mg/ℓ as the actual peak concentration

These conceptual models were used to estimate residual risk levels associated with the various remedial action alternatives proposed in this section  Peak concentrations for other COCs were several orders of magnitude below that of PCE

Residual Risk Assessment

The risk assessment presented in Appendix C documents the approach and calculations performed to estimate residual risks associated with the proposed alternatives  To select the most appropriate pathways and indicator chemical  the results of the OU 1 PHE were first reviewed  Groundwater modeling results were then compared to contaminant specific PRGs for OU 1  This comparison indicated that PCE is the most conservative contaminant to use in the risk assessment, that is  it contributes the highest risk to future groundwater receptors based on modeled contaminant concentrations at Woman Creek

Groundwater modeling was performed to estimate the concentration of PCE in groundwater using three conceptual models for OU 1, as described in the modeling summary above

Using groundwater modeling results with the most conservative exposure pathways, noncarcinogenic hazard indices and carcinogenic risk were calculated  The results of these calculations indicate that none of the calculated noncarcinogenic hazard indices approach unity and that the maximum calculated carcinogenic risk is for the scenario of no remediation of the source contaminant and discontinuing operations of the french drain and extraction well, (i e no action)  The maximum risks are listed below for each modeled scenario with alternative numbers listed in parenthesis

- no action scenarios (0  1)  1 99 x $10^{-6}$
- french drain institutional control scenarios (2, 3)  4 76 x $10^{-9}$
- remediation scenarios (4  5  6  7)  3 22 x $10^{-7}$

4 2 1 Alternative 0.  No Action

The NCP requires that the No Action Alternative be evaluated as a baseline alternative against which other alternatives can be compared This alternative assumes that acceptable groundwater contaminant concentrations would be achieved through natural degradation and dispersion of the groundwater COCs at OU 1, and that the site would eventually be abandoned Therefore no remedial actions would be initiated to reduce the risk from groundwater contaminants by actively treating the groundwater or subsurface soils The alternative assumes that operation of the treatment portion of the existing french drain system would be discontinued For costing purposes it is assumed that the french drain would be decommissioned under this alternative This would be accomplished by using a backhoe to excavate and remove sections of the drain

Groundwater monitoring activities would continue to monitor contaminant concentrations over time For the purposes of this detailed analysis a 30-year institutional control period is assumed for groundwater monitoring

The evaluation of the two threshold and five balancing criteria for Alternative 0 No Action are summarized as follows

Overall Protection of Human Health and the Environment

The no action alternative would be protective of human health based on exposure to OU 1 COCs at the Woman Creek location Concentrations of contaminants in groundwater would gradually be reduced over time due to physical, biological and chemical processes such as dispersion volatilization and biodegradation

Key ARARs would be met under this alternative In particular, the MCLs would continue to be achieved for groundwater COCs at Woman Creek This alternative would provide long term effectiveness in achieving the MCLs through natural processes which are essentially irreversible

A risk level of 1 99x$10^{-6}$ would be achieved at Woman Creek under this alternative Therefore the magnitude of residual risk that would result from the implementation of the No Action alternative falls well within the acceptable risk range of $10^{-4}$ to $10^{-6}$ Additionally risk from surface soil contaminants would remain within the acceptable risk range of $10^{-4}$ to $10^{-6}$

There would be no increase in potential risks to the public to on site workers or to the environment under the No Action alternative

Compliance With Applicable or Relevant and Appropriate Requirements

Chemical Specific ARARs

The results of groundwater modeling and monitoring indicate that groundwater at Woman Creek currently meets MCLs Modeling results projected to 400 years from 1969 also indicate that there will be no exceedance of MCLs within the 400-year period Groundwater modeling results demonstrate that the highest concentration of PCE during the 400-year period is 3 $60 \times 10^{-3}$ mg/$\ell$ for this alternative Assumptions of the model are discussed in Appendix B and have included factors for natural degradation but not volatilization of organics

Action Specific ARARs

Alternative 0 will comply with RCRA regulations 6 CCR 1007 3 Parts 264 and 265 if the CDPHE designates OU 1 a CAMU in accordance with 6 CCR 1007 3, 264 552(c) Under the No Action alternative, the contaminants would remain in place subject to natural degradation, volatilization and dispersion Groundwater monitoring would be conducted to detect direction and movement of hazardous constituents as specified in 6 CCR 1007 3 264 552(d)(3) The substantive requirements for disposal facilities under Parts 264 and 265 would be met through compliance with the CAMU rule

The No Action alternative would comply with the state solid waste disposal site and facility regulations since there are no exceedances of the MCLs at Woman Creek However since solid waste areas can be included in the CAMU it is believed this requirement is no longer appropriate as an ARAR

The air pollution regulations are not an ARAR for this alternative since there are no major earth moving activities or air emissions associated with this alternative

Location Specific ARARs

Alternative 0 is anticipated to comply with the laws and regulations specific to wetlands and species which use the wetlands There is a population of Preble s meadow-jumping mouse at the RFETS which is a non game species of special concern under state wildlife policy Once the french drain is decommissioned it is possible that wetland/riparian habitat areas would increase in size in the long term after a short term disturbance Prior to disturbance the State Division of Wildlife would be consulted on mitigation measures to lessen impacts to this species as well as others

Long Term Effectiveness and Permanence

The No Action alternative would involve only groundwater monitoring This alternative would not provide any additional protection for the environment and potential downgradient receptors because operation of the french drain which currently appears to be effective in capturing groundwater migrating away from OU 1 would be discontinued under this alternative

Residual concentrations of COCs may be acting as a continuing source at IHSS 119 1 The No Action alternative does not address treatment for residuals in either the groundwater or the soil The existing french drain system would not be operational, potentially allowing contaminated groundwater to migrate from OU 1 and to impact groundwater and soils outside of OU 1 However modeling indicates that under this alternative MCLs for groundwater COCs are currently achieved and would continue to be met at Woman Creek A five year review would be conducted to determine the continued effectiveness of this alternative

Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative would not satisfy the NCP preference for treatment as a principal element of the alternative because it does not directly result in treatment of contaminated groundwater The No Action alternative would not treat groundwater or soils and therefore would not reduce the toxicity mobility or volume of contaminants although natural processes would result in a reduction of contaminant concentrations over time

Short Term Effectiveness

Because no remedial action would be initiated no significant additional short term risks to the local community or environment would be created as a result of the No Action alternative at OU 1

There would be no additional potential impacts to workers as a result of this alternative Existing safety measures used for permanent workers and visitors would offer effective and reliable protection from the COCs associated with OU 1 Adherence to appropriate health and safety measures would be required for as long as monitoring activities are continued at OU 1

Implementability

The No Action alternative is readily implementable because it includes only the continuation of groundwater monitoring activities with installation of possibly four additional wells The implementability of this alternative would not be limited by the availability of services and materials nor would there be any significant technical or administrative difficulties associated with this alternative

Cost

Capital costs associated with Alternative 0 include decommissioning the french drain Post closure actıvıtıes for Alternatıve 0 ınclude groundwater monıtorıng for 30 years and ınstallatıon of four addıtıonal wells   The capıtal cost for thıs alternatıve ıs $154 700   The annual O&M cost for thıs alternatıve ıs $0  the cost for post-closure ıs $1 740 400   The total cost for thıs alternatıve ıs $1 895 100   A detaıled cost estımate for thıs alternatıve ıs ıncluded ın Appendıx E

4 2 2  Alternatıve 1.  Instıtutıonal Controls Wıthout the French Draın

Thıs alternatıve would rely on ınstıtutıonal controls to restrıct access to any wells ımpacted by OU 1 contamınants and prevent buıldıng constructıon above the areas known to be contamınated wıth VOCs   As wıth the No Actıon alternatıve  thıs alternatıve assumes that acceptable groundwater contamınant concentratıons would be achıeved through natural degradatıon  volatılızatıon, and dıspersıon of the COCs  and that the sıte would not be abandoned durıng the ınstıtutıonal control perıod   No remedıal actıons would be ınıtıated to reduce the rısk from groundwater contamınants by actıvely treatıng the groundwater or subsurface soıls   The alternatıve assumes that operatıon of the treatment portıon of the exıstıng french draın system would be dıscontınued

Thıs alternatıve presents the potentıal for the RFETS to be converted to a future ecologıcal reserve   The ınstıtutıonal controls consıdered here represent sıtewıde control of all areas of the RFETS   Groundwater monıtorıng, supplemented by ınstallatıon of addıtıonal wells  would be contınued to determıne ıf any changes occur ın contamınant concentratıons or ın contamınant mıgratıon patterns   Groundwater monıtorıng would contınue for as long as ınstıtutıonal controls are actıve at the sıte, or untıl ıt ıs determıned that monıtorıng ıs no longer requıred   For the purposes of thıs detaıled analysıs a 30-year ınstıtutıonal control perıod ıs assumed for groundwater monıtorıng

The evaluatıon of the two threshold and fıve balancıng crıterıa for Alternatıve 1   Instıtutıonal Controls Wıthout the French Draın are summarızed as follows

Overall Protection of Human Health and the Environment

This alternative would be protective of human health assuming that the institutional controls are properly implemented and that the site would not be abandoned during the institutional control period The french drain would not be used to capture contaminated groundwater but concentrations of contaminants in downgradient groundwater would gradually be reduced over time due to physical and chemical processes, such as dispersion volatilization and biodegradation

There would be no additional human health risk associated with this alternative because the entire RFETS site would be controlled eliminating access to OU 1 and therefore the potential for human exposure There would also be no increase in potential risks to the public or to on site workers under this alternative

Key ARARs would be met under this alternative In particular the MCLs would continue to be achieved for groundwater COCs at Woman Creek This alternative would provide long term effectiveness in achieving the MCLs, through natural processes which are essentially irreversible

Compliance With Applicable or Relevant and Appropriate Requirements

Chemical Specific ARARs

The results of groundwater modeling and groundwater monitoring indicate that groundwater at Woman Creek currently meets MCLs Modeling projected 400 years from 1969 also indicates that there will be no exceedance of MCLs within the 400-year period Groundwater modeling results demonstrate that the highest concentration of PCE during the 400-year period is 3 $60 \times 10^{-3}$ mg/ℓ for this alternative Assumptions of the model are discussed in Appendix B and have included factors for natural degradation but not volatilization of organics

Action Specific ARARs

The main difference between the No Action alternative and Alternative 1 is the extent of institutional controls at the RFETS This difference would not create a difference in the alternative s compliance with the key ARARs Alternative 1 will meet substantive requirements of the State RCRA program if CDPHE staff designates the OU 1 area as a CAMU under the recently adopted Subpart S provisions (6 CCR 1007 3 Part 264 Section 552) This alternative includes a 30-year groundwater monitoring program which complies with 6 CCR 1007 3 264 552(d)(3) Contaminants would be left in place subject to natural degradation volatilization and dispersion

Solid waste can be included in the CAMU and thus it is assumed that substantive portions of the State's solid waste regulations would not be appropriate to the CAMU and thus not an ARAR

The air pollution regulations are not an ARAR for this alternative since there would not be any air emission sources or major earth moving activities

Location Specific ARARs

Location specific ARARs associated with this alternative are focused on the protection of wetlands Decommissioning of the french drain could cause disturbance to a small portion of wetlands for 2 to 3 days Mitigation measures would be used to minimize the impact and to comply with DOE regulations on wetland protection as well as the State s Non Game Endangered or Threatened Species Conservation Act Coordination with State Division of Wildlife would be done to protect the population of Preble's meadow jumping mouse a state species of special concern

Long Term Effectiveness and Permanence

This alternative would minimize the human health risk associated with contaminated groundwater by restricting access to any wells impacted by OU 1 contaminants and by eliminating the possibility of building construction above areas known to be contaminated with VOCs This alternative would not provide any additional protection for the environment and potential downgradient receptors because operation of the french drain which currently appears to be effective in capturing groundwater migrating away from IHSS 119 1 would be discontinued under this alternative

This alternative does not address treatment for residuals in either the groundwater or subsurface soils The existing french drain system would not be operational potentially allowing contaminated groundwater to migrate from OU 1, and to impact groundwater and soils outside of OU 1 However modeling results indicate that under this alternative groundwater would continue to meet MCLs at Woman Creek A five year review would be conducted to determine the continued effectiveness of this alternative

Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative would not satisfy the NCP preference for treatment as a principal element of the alternative Because it does not propose treatment for contaminated groundwater or subsurface soils this alternative would not reduce the toxicity, mobility, or volume of contaminants although natural processes would result in a reduction of contaminant concentrations over time

Short Term Effectiveness

Because no remedial action would be initiated no additional short term risks to the local community or environment would be created by implementing this alternative

There would be no additional potential impacts to workers as a result of this alternative Existing safety measures used for permanent workers and visitors would offer effective and reliable protection from the COCs associated with OU 1 Adherence to appropriate health and safety measures would be required for as long as monitoring activities are continued at OU 1

Implementability

This alternative is readily implementable because it includes only institutional controls and groundwater monitoring The implementability of this alternative would not be limited by the availability of services and materials nor would there be any significant technical difficulties associated with this alternative Institutional controls proposed under this alternative such as deed restrictions could be implemented with no significant administrative problems

Cost

Capital costs associated with Alternative 1 include decommissioning the french drain Post closure activities for Alternative 1 include groundwater monitoring for 30 years and installation of four additional wells The capital cost for this alternative is $154 700 The annual O&M cost for this alternative is $0, and the cost for post-closure is $1,740 400 The total cost for this alternative is $1,895,100 A detailed cost estimate for this alternative is included in Appendix E

4 2 3 Alternative 2. Institutional Controls With the French Drain

This alternative is similar to Alternative 1 except that operation of the french drain and the Building 891 water treatment system would be continued The french drain would continue to capture contaminated groundwater migrating from the IHSS 119 1 source area Dilute concentrations of contaminated groundwater to the east of the operable unit would not be actively remediated by this alternative As with Alternative 1 institutional controls would be utilized to restrict access to any wells impacted by OU 1 contaminants and prevent building construction above the areas known to be contaminated with COCs

This alternative would also utilize groundwater monitoring programs to determine if any changes occur in contaminant concentrations or in contaminant migration patterns Groundwater monitoring would continue for as long as institutional controls are active at the site or until it is determined that monitoring is no longer required For the purposes of detailed analysis a 30 year institutional control period is assumed for groundwater monitoring The french drain would be decommissioned after monitoring confirms that COC concentrations have been reduced to acceptable levels

The evaluation of the two threshold and five balancing criteria for Alternative 2 Institutional Controls With the French Drain are summarized as follows

Overall Protection of Human Health and the Environment

Similar to Alternative 1 this alternative would be protective of human health assuming that the institutional controls are properly implemented and that the site would not be abandoned during the institutional control period In this alternative the french drain would be used to capture and treat contaminated groundwater and prevent downgradient migration of COCs

Key ARARs would be met under this alternative In particular the MCLs would continue to be achieved for groundwater COCs at Woman Creek This alternative would provide long term effectiveness in achieving the MCLs although the drain would have to be operated until all sources have been remediated in IHSS 119 1

A risk levels of 4 $76\times10^{-9}$ would be achieved at Woman Creek under this alternative Therefore the magnitude of residual risk that would result from the implementation of this alternative falls well below the acceptable risk range of $10^{-4}$ to $10^{-6}$ Additionally risk from surface soil contaminants would remain within the acceptable risk range of $10^{-4}$ to $10^{-6}$ There would no increase in potential risks to the public or to on site workers under this alternative because no additional actions would be initiated Existing health and safety procedures would effectively protect on site workers

Complıance Wıth Applıcable or Relevant and Appropnate Requırements

Chemıcal Specıfic ARARs

The results of groundwater modelıng and groundwater monıtorıng ındıcate that groundwater at Woman Creek currently meets MCLs  Modelıng results projected 300 years from 1969 also ındıcate that there wıll be no exceedance of MCLs wıthın the 300-year penod  Groundwater modelıng results demonstrate that the hıghest peak concentratıon of PCE durıng the 300-year penod ıs 8 62x10$^{-6}$ mg/$\ell$ under thıs alternatıve  Assumptıons of the model are dıscussed ın Appendıx B and have ıncluded factors for natural degradatıon but not volatılızatıon of organıcs

Actıon Specıfic ARARs

Alternatıve 2 wıll meet the substantıve requırements of the state RCRA program specıfic to past spılled waste, ıf CDPHE staff desıgnates the OU 1 area as a CAMU under 6 CCR 1007 3 264 552

The substantıve requırements ınclude

- Generators of hazardous waste
- Releases from solıd waste management unıts
- Closure of a dısposal facılıty under ınterım status and final status
- Post-closure of a dısposal unıt under final status

Solıd waste ıs allowed to be ıncluded ın the desıgnatıon of a CAMU  If the CAMU ıs adopted ıt ıs belıeved the state s solıd waste regulatıons would not be appropnate to the cırcumstances and thus would no longer be an ARAR.

Contamınants would be left ın place at the IHSS 119 1 area subject to collectıon and treatment at the french draın  There ıs a potentıal for some contamınants to be left ın place outsıde the area of the capture zone and collectıon system

The State s air pollution control regulations are not an ARAR for this alternative since there would not be a source of air emissions

Location Specific ARARs

Alternative 2 will not involve disruption of the current scenario at the site for an estimated 30 years Therefore impacts to wetland and riparian habitat areas are not anticipated to occur within this time period The populations of Preble s meadow jumping mouse a state species of special concern would continue on their current course until that time

Decommissioning of the french drain would involve a short term disruption to some portion of wetlands Mitigation measures would be used to minimize the impact and to comply with DOE regulations on wetland protection as well as the State s Non Game Endangered or Threatened Species Conservation Act

Long Term Effectiveness and Permanence

Under this alternative the existing french drain would continue to remove contaminated groundwater migrating from IHSS 119 1 This alternative would also minimize the human health risk associated with contaminated groundwater by restricting access to any wells impacted by OU 1 contaminants and by eliminating the possibility of building construction above areas known to be contaminated with VOCs The alternative would provide long term protection for potential human receptors assuming that the institutional controls initiated are guaranteed to remain in place

Residual concentrations of COCs may be acting as a continuing source at IHSS 119 1 This alternative does not address treatment for residuals in either the groundwater or subsurface soils However modeling indicates that under this alternative groundwater would continue to meet MCLs for the COCs at Woman Creek Concentrations of contaminants in groundwater would gradually be reduced over time due to physical and chemical processes such as dispersion volatilization and biodegradation A five-year review would be conducted to determine the continued effectiveness of this alternative

Contaminated materials generated as a result of this alternative include spent ion exchange resins from the Building 891 water treatment system These resins are currently regenerated on site There are no significant risks associated with handling these resins

Reduction of Toxicity, Mobility, or Volume Through Treatment

The continued operation of the french drain would reduce the mobility and volume of COCs in groundwater at OU 1 however residual concentrations of COCs would remain in subsurface soils and groundwater in IHSS 119 1

Extracted groundwater would be treated in the Building 891 water treatment system This is a destructive treatment process and thus would result in decreased toxicity Contaminant removal through groundwater extraction would be irreversible, however, DNAPLs in IHSS 119 1 may continue to act as a source

Short Term Effectiveness

This alternative includes the implementation of institutional controls the continued operation of the french drain system, and groundwater monitoring Because no additional remedial action would be initiated, no additional short term risks to the local community or environment would be created by implementing this alternative

There would be no additional potential impacts to workers as a result of this alternative Existing safety measures used for permanent workers and visitors would offer effective and reliable protection from the COCs associated with OU 1 Adherence to appropriate health and safety measures would be required for as long as monitoring activities are continued at OU 1

Implementability

This alternative is readily implementable because it includes only institutional controls the continued operation of the french drain and Building 891 water treatment system and the continuation of groundwater monitoring activities The implementability of this alternative would not be limited by the availability of services and materials nor would there be any significant technical difficulties associated with this alternative There are no technical problems associated with continued operation of the existing french drain system Groundwater monitoring would effectively track any additional migration of COCs

Institutional controls proposed under this alternative such as deed restrictions could be implemented with no significant administrative problems

Cost

Capital costs associated with Alternative 2 include decommissioning of the french drain O&M costs for Alternative 2 includes operation of the Building 891 water treatment system and groundwater monitoring for 30 years Capital cost for this alternative is $149 600 The annual O&M cost for this alternative is $15,603 300, the post-closure cost is $1 740 400 The total cost for this alternative is $17 493,300 A detailed cost estimate for this alternative is included in Appendix E

4 2 4 Alternative 3, Modified French Drain With Additional Extraction Wells

Similar to Alternative 2, this alternative would continue to operate the existing french drain system However approximately four to six additional six inch diameter groundwater extraction wells would be added to the existing system to enhance its effectiveness in capturing contaminated groundwater migrating from the IHSS 119 1 sources and other areas The additional wells could be installed in the southeastern corner of the operable unit to capture any contaminated groundwater potentially flowing around the french drain in the IHSS 119 1 source area to assist the existing recovery well in front of the french drain in a suspected low permeability sandstone lens which may potentially form a conduit for groundwater transport beneath the drain or in the area south of Building 881 to enhance the recovery of contaminated groundwater in that area

Based on the performance of the french drain and existing extraction well the new extraction wells are expected to remove less than one gpm of groundwater combined Each well would be equipped with a sump pump with high and low level switches that would pump intermittently This would ensure that the pumps would not be burned out by operating in a dry well Groundwater recovered from the new extraction wells would be routed to the french drain system to be transferred to the Building 891 water treatment system and treated with the UV/peroxide/ion exchange process

As with the institutional controls alternatives, this alternative would also continue groundwater monitoring activities to determine if any changes occur in contaminant concentrations or in contaminant migration patterns Groundwater monitoring would continue for as long as institutional controls are active at the site or until it is determined that monitoring is no longer required For the purposes of this detailed analysis a 30-year institutional control period is assumed for groundwater monitoring The french drain would be decommissioned after monitoring confirms that COC concentrations have been reduced to acceptable levels

The evaluation of the two threshold and five balancing criteria for Alternative 3 Modified French Drain With Additional Extraction Wells are summarized as follows

<u>Overall Protection of Human Health and the Environment</u>

This alternative would be protective of human health and the environment assuming that the site would not be abandoned during the institutional control In this alternative, the french drain and several additional extraction wells would be used to capture contaminated groundwater and prevent downgradient migration of COCs Low level groundwater contamination east of the french drain would also be addressed in this alternative by installing one or more of the new extraction wells in this area

Key ARARs would be met under this alternative Specifically MCLs would continue to be achieved for groundwater COCs at Woman Creek This alternative would provide long term effectiveness in achieving the MCLs

Risk levels achieved by this alternative would be the same as those achieved under Alternative 2 however these levels would be achieved in a shorter time because the additional groundwater extraction wells would increase the rate at which contaminated groundwater is removed Therefore the magnitude of residual risk that would result from the implementation of Alternative 3 falls well below the acceptable risk range of $10^{-4}$ to $10^{-6}$ Additionally, risk from surface soil contaminants would remain within the acceptable risk range of $10^{-4}$ to $10^{-6}$

There would be no increase in potential risks to the public or to on site workers under this alternative Existing health and safety procedures would effectively protect on-site workers

Compliance With Applicable or Relevant and Appropriate Requirements

Chemical Specific ARARs

The results of groundwater modeling and groundwater monitoring indicate that groundwater at Woman Creek currently meets MCLs Modeling results projected 300 years from 1969 also indicate that there will be no exceedance of MCLs within the 300-year period Groundwater modeling results demonstrate that the highest concentration of PCE during the 300-year period is 4 $76 \times 10^{-9}$ mg/$\ell$ for this alternative Assumptions of the model are discussed in Appendix B and have included factors for natural degradation but not volatilization of organics

Action Specific ARARs

Alternative 3 compliance with action-specific RCRA program requirements is similar to that described under Alternative 2 RCRA requirements are relevant and appropriate and compliance of the alternative with the substantive requirements of Parts 262 Part 264 and Part 265 depends in part on implementation of Subpart S requirements OU 1 designated as a CAMU would allow some contaminants to be left in place after closure at the 119 1 and 119 2 IHSS locations Compliance with releases from solid waste management units Subpart F closure of a disposal unit Subpart G and post- closure of a disposal unit Subpart H can be achieved with the alternative

Solid waste can be designated as part of the CAMU and therefore compliance with the State solid waste regulations would not be appropriate The MCLs are met at Woman Creek according to groundwater modeling results

The additional extraction wells would be constructed in accordance with the substantive parts of the Colorado Water Well and Pump Installation Regulations (2 CCR 402 2) Therefore compliance with this ARAR is anticipated for Alternative 3

Location-Specific ARARs

Alternative 3 is anticipated to comply with the location specific ARARs Laws and regulations specific to wetlands and species which use wetlands will be complied with if Alternative 3 is implemented at OU-1 When the french drain is decommissioned it is possible that the wetland/riparian habitat areas would increase in size in the long term, after short term disturbance of the wetland areas Prior to disturbance, the State Division of Wildlife would be consulted on mitigation measures, to lessen impacts to species of concern such as Preble s meadow jumping mouse

Long Term Effectiveness and Permanence

Under this alternative the existing french drain would continue to remove contaminated groundwater migrating from IHSS 119 1 Therefore the residual risk would gradually be reduced over time

This alternative would also minimize the human health risk associated with contaminated groundwater by restricting access to any wells impacted by OU 1 contaminants and by eliminating the possibility of building construction above areas known to be contaminated with VOCs The alternative would provide long term protection for potential human receptors assuming that the institutional controls initiated are guaranteed to remain in place

This alternative would also be effective in protecting the environment over the long term by addressing groundwater with low levels of contaminants that is potentially flowing around the east end of the french drain system and could otherwise potentially impact on groundwater and soils outside of OU-1 However, modeling indicates that under this alternative groundwater would continue to meet MCL for PCE at Woman Creek Concentrations of contaminants in groundwater would gradually be reduced over time due to physical and chemical processes such as dispersion volatilization and biodegradation A five year review would be conducted to determine the effectiveness of this alternative

Contaminated materials generated as a result of this alternative include spent ion exchange resins from the Building 891 water treatment system These resins are currently regenerated on site There are no significant risks associated with handling these resins

Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative would reduce the mobility and volume of contaminants in OU 1 through continued operation of the french drain and the addition of several groundwater extraction wells The french drain effectively reduces the migration of contaminated groundwater from OU 1

Groundwater extraction would reduce the volume of COCs in groundwater however residual concentrations of COCs would remain in subsurface soils and groundwater in IHSS 119 1 The french drain and extraction wells would also continue to prevent migration of COCs beyond OU 1 thus reducing the mobility of these contaminants

Extracted groundwater would be treated in the Building 891 water treatment system This is a destructive treatment process and thus would result in decreased toxicity Contaminant removal through groundwater extraction would be irreversible, however, DNAPLs may continue to act as a source

Short Term Effectiveness

Because the only additional remedial action initiated by this alternative would be the extraction well installation, a procedure that can be accomplished in a relatively short period of time the additional short term risks to the local community or environment would be minimized

The only potential impacts to workers implementing this alternative would be those associated with the installation of the new extraction wells These potential impacts would be minimized through existing worker safety procedures governing construction activities at RFETS Existing safety measures for the french drain operation and monitoring activities would offer effective protection for workers and visitors at OU 1 Adherence to appropriate health and safety measures would be required for as long as monitoring activities are continued at OU 1

Implementing this alternative would have limited impacts on the environment or the public at OU 1 Installing additional extraction wells would have minor impacts on site soils and flora

Implementability

This alternative is also readily implementable It includes the continuation of groundwater monitoring activities the continued operation of the french drain, and installation of several additional groundwater extraction wells The implementability of this alternative would not be limited by the availability of services and materials nor would there be any significant technical or administrative difficulties associated with this alternative Continuation of groundwater monitoring activities would effectively track any additional COC migration Also implementing this alternative would not limit the ability to perform future remedial actions if they are determined to be necessary

Extraction wells can be installed with little difficulty using standard drilling techniques and standard construction materials that are commonly used for well construction and are readily available Operating the additional extraction wells would not require any additional specialized personnel or training The Building 891 water treatment system has sufficient capacity to treat the quantities of water extracted by the additional wells

No administrative difficulties are anticipated under this alternative Coordinating activities with agencies and obtaining the appropriate permits is not expected to present any problems

<u>Cost</u>

Capital costs for this alternative include the costs for four new groundwater extraction wells (six inch diameter 20-foot depth) and associated piping pumps and instrumentation The capital cost for Alternative 3 is $305 000 O&M and post-closure activities for Alternative 3 include the operation of the additional extraction wells and the Building 891 water treatment system and groundwater monitoring The present worth value for O&M for Alternative 3 is $15 603 300 the post-closure cost is $1,740 400 The total cost of this alternative is therefore $17 648,700 A detailed cost estimate for capital and O&M costs for this alternative is included in Appendix E

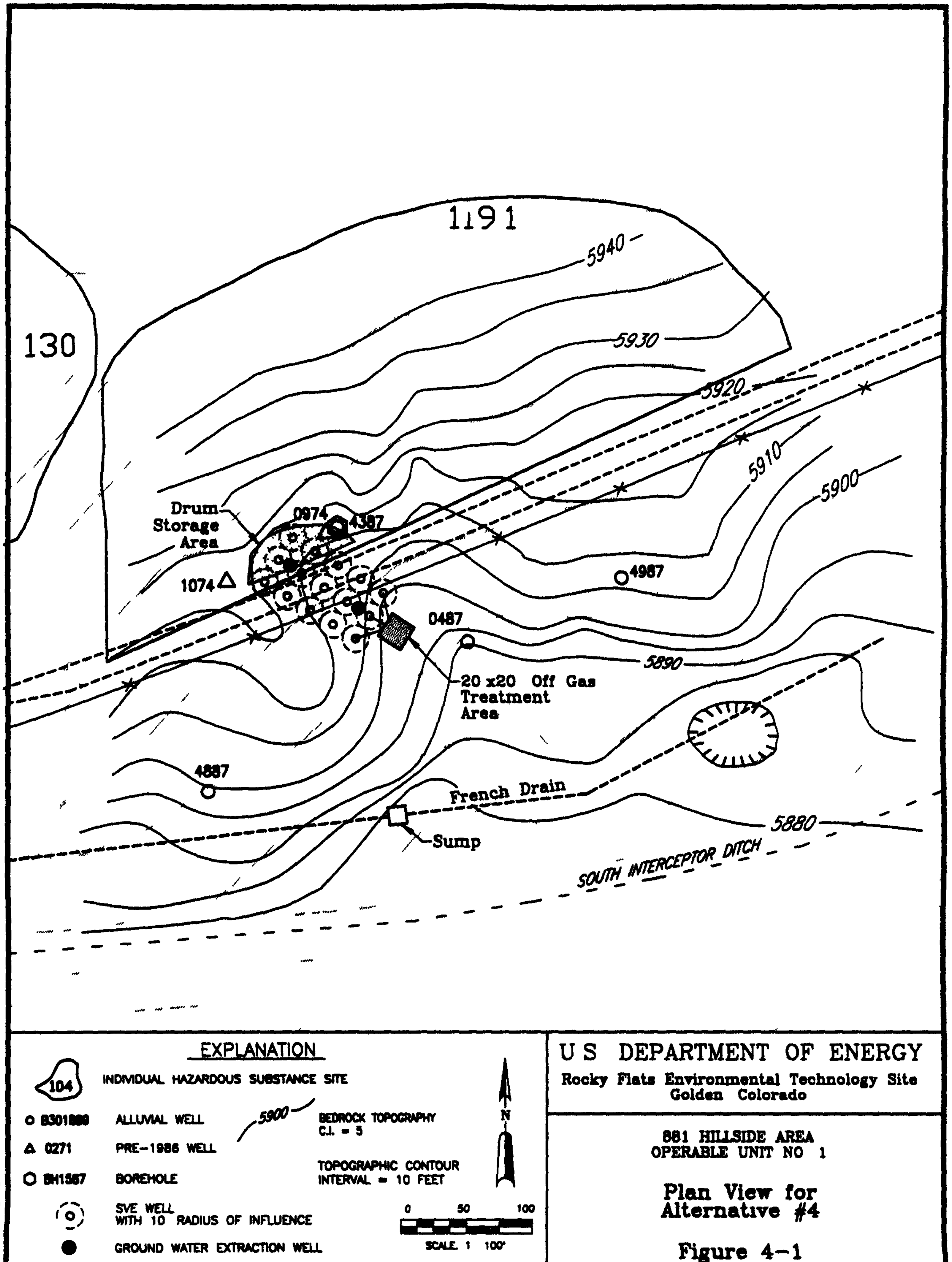
4 2 5 <u>Alternative 4. Groundwater Pumping and Soil Vapor Extraction</u>

This alternative would remove contaminated groundwater by pumping it to the surface and treatıng ıt ın the Buıldıng 891 water treatment system It would also remedıate resıdual sources of contamınatıon ın the subsurface soıls by SVE The alternatıve targets all contamınants dıssolved ın the groundwater as well as sources of resıdual organıc contamınatıon such as DNAPLs A detaıled soıl gas survey consıstıng of approxımately 100 soıl gas probes would be conducted to determıne more precıse locatıons of resıdual contamınants The survey would take approxımately sıx months The results of thıs survey would be used to determıne areas requırıng treatment For the purposes of detaıled analysıs however only the prevıously ıdentıfied source area wıthın IHSS 119 1 wıll be consıdered

The treatment zone would first be dewatered by pumpıng from the exıstıng groundwater extractıon well and two addıtıonal extractıon wells These pumps would be operated ıntermıttently to keep the source area dewatered All groundwater collected would be pıped to the french draın sump for transfer to the Buıldıng 891 water treatment system Inıtıal dewaterıng ıs expected to take 60 to 80 days, wıth ıntermıttent operatıon contınuıng afterwards to keep the treatment zone dewatered throughout the entıre remedıal actıon Approxımately 80 000 gallons of groundwater ıs expected to be recovered, assumıng that thıs alternatıve ıs ımplemented durıng a low water table elevatıon perıod

Once dewatered SVE would be applıed at the source area to volatılıze and remove any resıdual sources of organıc contamınatıon Approxımately 15 vapor extractıon wells would be drılled ın the source area and connected to a vacuum pump thus ınducıng a vapor flow ın the subsurface toward the extractıon wells The ıncreased vapor flow would volatılıze aqueous adsorbed and free phase contamınants and remove vapor phase contamınants wıth the evacuated aır A plan vıew of the SVE system layout ıs ıllustrated ın Fıgure 4-1

The sıze and number of vapor extractıon wells pump sızes flow rates and vacuum requırements were determıned based on the results of the ongoıng SVE treatabılıty study at OU 2 ın conjunctıon wıth the model HyperVentılate Prelımınary results from the OU 2 study ındıcate a 45 foot radıus of ınfluence was achıeved ın the sılty sand matrıx of OU 2 soıls Thıs radıus of ınfluence was estımated by extrapolatıng observatıons of a sıx ınch $H_2O$ vacuum 20 feet from




EXPLANATION



U S DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

Plan View for Alternative #4

Figure 4-1

OU1-SVE1 DWG

the extraction well The extraction well recovers two standard cubic feet per minute for each foot of well screening using a vacuum pump which produces 140 inches $H_20$ of vacuum at its inlet The permeabilities observed at OU 2 have ranged from 0 1 darcies to 1 darcy which are an order of magnitude above those observed at OU 1 Initial contaminants concentrations at OU 2 were similar to those in the OU 1 source area however physical features of the OU 2 site including an excavated ditch near the treatability study zone have an undetermined influence on system parameters For this reason estimates for parameters at OU 1 were made using technical literature to supplement the results from OU 2 Based on these two sources it is assumed that four inch diameter extraction wells operated at 10 scfm and 120 inches $H_20$ of vacuum would have a radius of influence of approximately 10 feet at OU 1

Off gas from the SVE system would be treated with either GAC or catalytic oxidation prior to discharge For costing purposes, GAC usage was estimated based on expected COC concentrations in extracted soil gas Based on soil sample data from the Phase III RFI/RI Henry s Law was used to estimate the partitioning of COCs in the soil vapor Calculations suggest that the equilibrium concentrations of each VOC would be on the order of 1 mg/ℓ However, because the quantities of COCs at OU 1 are assumed to be small equilibrium concentrations are not likely to be reached in extracted soil vapor Therefore concentrations one order of magnitude below the Henry s Law calculated equilibrium values were used to determine the usage rate for GAC in the off gas treatment system These concentrations are considered to be conservative estimates of soil vapor COC concentrations Based on these assumptions the SVE off gas treatment system would require approximately 3,000 pounds of fresh GAC every three months

Because of the low adsorption efficiency of 1 1 DCE on GAC the proposed SVE system would require two skid-mounted GAC vessels in series each containing 1 500 pounds of activated carbon The activated carbon in the vessels would be replaced approximately every three months the spent carbon could be treated at an off site regeneration facility

Off gas from the vacuum pump would be monitored to determine the effectiveness of the SVE system Intermittent operation could be employed to increase the recovery of residual sources and decrease operating costs

The remediation time frame for this alternative would be two years including six months for soil gas surveying four years for soil vapor extraction and dewatering operations and six months for mobilization/demobilization The french drain would be decommissioned upon completion of remedial activities

The evaluation of the two threshold and five balancing criteria for Alternative 4 Groundwater Pumping and Soil Vapor Extraction is summarized as follows

Overall Protection of Human Health and the Environment

This alternative would be protective of human health and the environment by removing the contaminants from both groundwater and subsurface soils Exposure potential would be reduced by reducing the contaminant concentrations and removing the source The french drain would continue to capture contaminated groundwater and prevent downgradient migration of COCs until remediation activities are completed

This alternative would be protective of the environment both downgradient of and within OU 1 because in addition to utilizing the existing french drain to intercept contaminated groundwater migrating away from OU-1 the source at IHSS 119 1 would be treated using SVE

Key ARARs would be met under this alternative In particular MCLs would continue to be achieved for groundwater COCs at Woman Creek providing long term effectiveness In addition this alternative would provide a large degree of permanence because the source area at IHSS 119 1 would be treated However, there is also some degree of uncertainty as to the level of cleanup that could be achieved for DNAPLs with SVE

Because this alternative would remediate the source at IHSS 119 1 a risk level of 3 $22 \times 10^{-7}$

would be achieved at Woman Creek Therefore the magnitude of residual risk that would result from the implementation of this alternative falls well below the acceptable risk range of $10^{-4}$ to $10^{-6}$ Additionally risk from surface soil contaminants would remain within the acceptable risk range of $10^{-4}$ to $10^{-6}$

This alternative would be completed in five years During implementation there would be no unacceptable short term risks to the public There may be potential risks to on site workers from exposure to COCs in groundwater or soil vapor and safety hazards associated with drilling and construction activities However risks would be minimized through standard health and safety practices

Compliance With Applicable or Relevant and Appropriate Requirements

Chemical Specific ARARs

The results of groundwater modeling and groundwater monitoring indicate that groundwater at Woman Creek currently meets MCLs Modeling projected indicate that there will be no exceedance of MCLs at Woman Creek through implementation of this alternative Groundwater modeling results demonstrate that the highest concentration of PCE is 5 $94 \times 10^{-4}$ for this alternative The peak concentration occurs over a short duration and is below the MCL Assumptions of the model are discussed in Appendix B and have included factors for natural degradation but not volatilization of organics

Action Specific ARARs

Compliance with the RCRA program, involving releases of hazardous constituents from SWMUs under Subpart F is a relevant and appropriate requirement Since remediation is focused mostly on the source of contamination the CAMU is a relevant and appropriate requirement for OU 1 Residual contamination may be left in places in areas of the unit however the overall quantity of constituents will be low Compliance with the closure requirements as a disposal unit can be achieved with Alternative 4 under the CAMU approach

Using a soil vapor extraction treatment system will create a temporary RCRA unit as the system treats hazardous waste constituents Therefore the temporary unit requirements of Subpart S (6 CCR 1007 3 Subsection 264 553) are applicable to this treatment unit In addition any pre filters HEPA filters and activated carbon used to remove volatile organics in the off gas treatment require compliance with the following RCRA provisions

- identification of hazardous waste (Part 261)
- air emission standards for process vents (Subsections 264 1032 and 264 1033)
- air emission standards for equipment leaks (Subsections 264 1056 and 1057)
- land disposal restrictions (Part 268)

It is anticipated that the applicable requirements of RCRA can be complied with in operating and decommissioning the SVE treatment unit and residuals

The Colorado solid waste regulations are not appropriate to the CAMU unit created but are an ARAR for disposal of any residual materials that are not hazardous waste If solid waste disposal is necessary with the alternative, it will be in accordance with 6 CCR 1007 2 and the solid waste disposal regulations

Installation of additional extraction wells would be in accordance with the Colorado Water Well and Pump Installation Regulations (2 CCR 402 2) Compliance with this action-specific ARAR would be achieved

The State s air pollution control Regulation 7, for the control of VOC emissions is an ARAR and will be achieved with this alternative It is anticipated the level of emissions will be below the two ton/yr (two lbs/hr) threshold for use of reasonably available control technology (RACT)

Location Specific ARARs

Laws and regulations specific to wetlands and species which inhabit wetlands will be complied with if this alternative is implemented There would be a short term impact to wetlands from decommissioning the french drain but the long term impact may be an increase in wetland areas The State Division of Wildlife would be consulted prior to disturbance of wetland habitat and to implement adequate mitigation measures to protect species of special concern

Long Term Effectiveness and Permanence

Under this alternative the source area at IHSS 119 1 would be remediated and the existing french drain extraction well, and Building 891 water treatment system would continue to extract and treat contaminated groundwater migrating from IHSS 119 1 Therefore the residual risk would be reduced as compared to the no action and institutional controls alternatives

There is some uncertainty that SVE will effectively remediate the residual COCs at IHSS 119 1 due to the low permeability of the soils and the general lack of documented experience in effective DNAPL treatment at any site If residual COCs are not effectively removed during remedial activities, they may continue to act as a source of groundwater contamination

Following treatment of the source, contaminated groundwater within OU 1 would continue to migrate away from IHSS 119 1 Modeling indicates that under this alternative groundwater would continue to meet MCLs for the COCs at Woman Creek A five year review would be conducted, however to determine the effectiveness of this alternative

This alternative would provide long-term protection for potential human receptors and minimize the human health risk associated with contaminated groundwater by continuing to achieve MCLs However although the MCLs will continue to be achieved with this alternative by remediating the soils and groundwater, this alternative may not be completely effective at removing DNAPLs if they are present at OU 1

Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative satisfies the NCP preference for treatment as a principal element of the alternative This alternative would effectively reduce the mobility and volume of contaminants in OU 1 by removing any secondary source of contaminants from the subsurface Groundwater extraction would reduce the volume of COCs in groundwater, and soil vapor extraction would remove COCs from the unsaturated zone Removing the secondary sources of contaminants in conjunction with the continued operation of the french drain and extraction well will also reduce their mobility by preventing potential additional migration

Extracted groundwater would be treated in the Building 891 water treatment system This is a destructive treatment process and thus would result in decreased toxicity GAC from the SVE off gas treatment system would be regenerated off site resulting in additional reduction in TMV

Contaminated materials generated as a result of this alternative include GAC from the off gas treatment system and spent ion exchange resins from the Building 891 water treatment system GAC could be shipped off site to be regenerated, and ion exchange resins would be regenerated on site There are no significant risks associated with handling and shipping either the spent activated carbon or ion exchange resins

Short Term Effectiveness

Potential short term impacts on the environment associated with this alternative include a minor amount of disturbance to the soil and displacement or loss of vegetation during construction activities such as building and drilling Additional short term risks to the public are minimal for this alternative

Potential risks to workers during remediation activities include potential exposures to COCs in extracted groundwater or soil vapor There are also safety hazards associated with drilling and other construction activities Risks to workers would be minimized through standard construction and process equipment operation safety practices

Implementability

This alternative would be readily implementable  Soil vapor extraction is a commonly used technology that does not require any unique or unusual equipment  The implementability of this alternative would not be limited by the availability of services and materials  nor would there be any significant technical or administrative difficulties associated with this alternative

Implementing this alternative would not limit the ability to perform future remedial actions, if any are determined to be necessary  Groundwater monitoring programs  continued under this alternative  would continue to track any movement of COCs

Vapor extraction wells can be installed using standard drilling techniques and standard construction materials that are readily available  Operation of the SVE system would not require highly specialized personnel or training  Spent GAC from the off-gas treatment system could be sent off site for regeneration  Spent ion exchange resin from the Building 891 water treatment system would be sent off site for appropriate disposal  Administrative requirements for this alternative would include obtaining an air emissions permit for the SVE off gas

Cost

Costs for this alternative include the costs for the following items

- soil gas survey (approximately 100 probes)
- two  groundwater extraction wells (six inch diameter  20-foot depth)
- 15 vapor extraction wells (four inch diameter  20-foot depth)
- two vapor extraction systems  with blowers  filters  and other appurtenances
- activated carbon adsorption system (two vessels containing 1 500 pounds each)
- associated piping, pumps  and instrumentation
- UV/peroxide/ion exchange water treatment system operation
- groundwater monitoring for 30 years

The capital cost for Alternative 4 is $929,300 O&M and post closure activities for Alternative 4 include the operation of the SVE system for one year the operation of the existing french drain and Building 891 water treatment system until completion of remediation and groundwater monitoring for 30 years The present worth of the O&M costs for this alternative is $5 358 700 the post closure cost is $1 853 800 The total cost of this alternative is $8 141 800 A detailed cost estimate for capital and O&M costs for this alternative is included in Appendix E

### 4 2 6 Alternative 5. Groundwater Pumping and Soil Vapor Extraction With Thermal Enhancement

This alternative would remove contaminated groundwater by pumping it to the surface and treating it in the Building 891 water treatment system It would also remediate residual sources of contamination in the subsurface soils by SVE with thermal enhancement The alternative targets all contaminants dissolved in the groundwater as well as sources of residual organic contamination such as DNAPLs Initially a detailed soil gas survey, consisting of approximately 100 soil gas probes would be conducted to determine more precise locations of residual contaminants The survey would take approximately six months The results of this survey would be used to determine areas requiring treatment For the purposes of this detailed analysis only the previously identified source area within IHSS 119 1 will be considered for treatment

As with Alternative 4 the treatment zone would first be dewatered by pumping from the existing groundwater extraction well and two additional extraction wells All groundwater collected would be piped to the french drain sump for transfer to the Building 891 water treatment system Initial dewatering is expected to take 60 to 80 days with intermittent operation continuing afterwards to keep the treatment zone dewatered throughout the entire remedial action Approximately 80,000 gallons of groundwater are expected to be recovered

Once dewatered, thermally enhanced SVE would be applied to the treatment zone to volatilize and remove any residual sources of organic contamination Just as with Alternative 4 approximately 15 vapor extraction wells would be drilled in the source area The SVE system utilized in this alternative would be the same as was described for Alternative 4 based on the results of the OU 2 treatability study To reduce the remediation time frame subsurface temperatures would be raised to approximately 260 °C using radio frequency antennae All of the vapor extraction wells would be constructed to accommodate the RF antennae The increased vaporization caused by the elevated temperatures would result in a reduction in remediation time as compared to unenhanced SVE

Off gas from the SVE system would be treated with GAC or catalytic oxidation prior to discharge as described for Alternative 4 The proposed SVE system would require two skid mounted GAC vessels in series each containing 1 500 pounds of activated carbon The activated carbon in the vessel would be replaced approximately every three months the spent carbon could be treated at an off site regeneration facility Carbon replacement may be required more frequently than every three months depending on the efficiency of the RF heating process

Off gas from the vacuum pump would be monitored to determine the effectiveness of the enhanced SVE system Intermittent operation could be employed to increase the recovery of residual sources and decrease operating costs The remediation time frame for this alternative is three years, including six months for soil gas surveying two years for soil vapor extraction and dewatering operations, and six months for mobilization/demobilization The french drain would be decommissioned upon completion of remedial activities

The evaluation of the two threshold and five balancing criteria for Alternative 5 Groundwater Pumping and Soil Vapor Extraction With Thermal Enhancement are summarized as follows

<u>Overall Protection of Human Health and the Environment</u>

This alternative would protect human health and the environment by removing the contaminants from both groundwater and subsurface soils Exposure potential would be reduced by reducing the contaminant concentrations and removing the source The existing french drain and extraction well would continue to capture contaminated groundwater and prevent downgradient migration of COCs

This alternative would be protective of the environment both downgradient of and within OU 1 because in addition to utilizing the existing french drain to intercept contaminated groundwater migrating away from OU 1 the source at IHSS 119 1 would be remediated

RF heating may have some negative impacts on the soils at OU 1 due to the high temperatures that are reached during operation While the elevated temperatures may increase the effectiveness of treatment for the COCs, they may be harmful to subsurface biota

Key ARARs would be met for this alternative In particular modeling shows that MCLs would continue to be achieved for groundwater COCs at Woman Creek providing long term effectiveness In addition this alternative would provide a large degree of permanence because the source area at IHSS 119 1 would be treated However there is also some degree of uncertainty as to the level of cleanup that could be achieved for source area DNAPLs with the enhanced SVE technology

Because this alternative would remediate the source at IHSS 119 1 modeling shows that a risk level of $3\ 22 \times 10^{-7}$ would be achieved at Woman Creek Therefore the magnitude of residual risk that would result from the implementation of this alternative falls well below the acceptable risk range of $10^{-4}$ to $10^{-6}$ Additionally, risk from surface soil contaminants would remain within the acceptable risk range of $10^{-4}$ to $10^{-6}$

Alternative 5 would be completed within three years During implementation there would be no unacceptable short term risks to the public There may be potential risks to on-site workers from exposure to COCs in groundwater or soil vapor and safety hazards associated with drilling construction activities, and operating the RF heating elements However, risks would be minimized through standard health and safety practices

## Compliance With Applicable or Relevant and Appropriate Requirements

### Chemical Specific ARARs

The results of groundwater modeling and groundwater monitoring indicate that groundwater at Woman Creek currently meets MCLs  Modeling results indicate that there will be no exceedance of MCLs at Woman Creek through implementation of this alternative  Groundwater modeling results demonstrate that the highest concentration of PCE is 5 $94 \times 10^{-4}$ mg/$\ell$ for this alternative  The peak concentration occurs over a short duration and is below the MCL  Assumptions of the model are discussed in Appendix B and have included factors for natural degradation but not volatilization  Alternative 5 and Alternative 4 are the same in terms of compliance with ARARs with few exceptions  The exceptions are noted in the following discussions of action specific and location specific ARARs

### Action Specific ARARs

The action specific ARARs associated with Alternative 5 are the same as presented in Alternative 4  Compliance with RCRA requirements for a temporary unit  CAMU  identification of hazardous waste  storage of hazardous waste  disposal of hazardous waste, and organic air emissions and leaks from the treatment unit will be achieved  The possible difference in the two alternatives may be the amount of organic constituents left in the OU 1 general area  It is possible that the thermal enhancement will leave slightly less contaminant pockets and soil vapor around extraction well locations, assuming air drying techniques are effective and the vapor generation rate is controlled  Closure of the CAMU would involve less contaminants left in place

Other action specific ARARs are anticipated to be complied with in the same manner as was discussed under Alternative 4

Location Specific ARARs

The areas of heaviest organic contamination are at IHSS 119 1 and 119 2 Assuming additional extraction wells are placed around these areas away from the french drain and Pond C 1 destruction of riparian vegetation and fauna during thermal enhancement will be minimal Therefore the habitat and fauna such as Preble s meadow-jumping mouse will remain intact This species is of special concern not threatened or endangered under State or Federal law It is anticipated that compliance with DOE wetland protection regulations and the State s law concerning non game species will be achieved with implementation of this alternative Should it be necessary riparian habitat would be replaced if it is destroyed by the thermal technology

Impacts from decommissioning the french drain would be the same as has been discussed for all previous alternatives The wetland protection regulations and non game species laws would be complied with if this alternative is selected

Long Term Effectiveness and Permanence

Similar to Alternative 4 this alternative would remediate the source area at IHSS 119 1 and the existing french drain extraction well and Building 891 water treatment system would continue to extract and treat contaminated groundwater migrating from IHSS 119 1 Therefore the residual risk would be reduced as compared to the no action and institutional control alternatives

This alternative may provide more effective and permanent treatment as compared to Alternative 4 because enhancing SVE with RF heating may more effectively remove residual COCs trapped within the less permeable soils at OU 1 However it is uncertain whether enhanced SVE or other in situ technologies can effectively remediate DNAPLs at 119 1 due to the general lack of documented success in treating DNAPLs at any site

This alternative would provide long-term protection for potential human receptors and minimize the human health risk associated with contaminated groundwater by continuing to achieve groundwater MCLs at Woman Creek However although this alternative may continue to effectively achieve the MCLs by remediating the soils and groundwater it may not be completely effective at removing DNAPLs if they are present at OU 1 Following treatment of the source contaminated groundwater within OU 1 would continue to migrate away from IHSS 119 1 Modeling indicates that under this alternative groundwater would continue to meet MCLs for COCs at Woman Creek A five year review would be conducted to determine the continued effectiveness of this alternative

Contaminated materials generated as a result of this alternative include spent carbon from the SVE off gas treatment system and spent ion exchange resins from the Building 891 water treatment system There are no significant risks associated with handling and shipping either the spent carbon or the ion exchange resins

Reduction of Toxicity, Mobility, or Volume Through Treatment

This alternative satisfies the NCP preference for treatment as a principal element of the alternative This alternative would effectively reduce the mobility and volume of contaminants in OU 1 by removing any secondary source of contaminants from the subsurface Groundwater extraction would reduce the volume of COCs in groundwater and soil vapor extraction would remove COCs from the unsaturated zone Removing the secondary sources of contaminants would also reduce their mobility by preventing potential additional migration

Extracted groundwater would be treated in the Building 891 water treatment system This is a destructive treatment process and thus would result in decreased toxicity GAC from the SVE off gas treatment system could be regenerated off site resulting in additional reduction in toxicity

Contaminated materials generated as a result of this alternative include activated carbon from the off gas treatment system and spent ion exchange resins from the Building 891 water treatment system Both wastes would be shipped off site for treatment and eventual disposal

There are no significant risks associated with handling and shipping either the spent activated carbon or ion exchange resins

Short Term Effectiveness

Potential short term impacts on the environment associated with this alternative include a minor amount of disturbance to the soil and displacement or loss of vegetation during construction activities In situ soil heating may have additional impacts on subsurface biota due to the high temperatures that are reached during operation Potential short term impacts to the public are minimal under this alternative

Potential risks to workers during remediation activities include potential exposures to COCs in extracted groundwater or soil vapor There are also safety hazards associated with drilling and other construction activities as well as with the operation of the RF heating devices Risks to workers would be minimized through standard construction and process equipment operation safety practices

Implementability

This alternative would be readily implementable Soil vapor extraction is a proven and commonly used technology that does not require any unique or unusual equipment Although RF heating is a less common technology, it is readily available through specialized vendors The implementability of this alternative would not be limited by the availability of services and materials nor would there be any significant technical or administrative difficulties associated with this alternative

Implementing this alternative would not limit the ability to perform future remedial actions if any are determined to be necessary Groundwater monitoring continued under this alternative would to track any movement of COCs

Vapor extraction wells can be installed using standard drilling techniques and standard construction materials that are readily available Operation of the SVE system would not require highly specialized personnel or training however using the RF heating antennae would require a certain amount of special training or assistance from the vendor The RF antennae can be easily installed in one or several of the vapor extraction wells and can be easily moved from one well to another, as required RF heating does not produce any residuals

Administrative requirements for this alternative would include obtaining an air emissions permit for the SVE off gas Spent GAC from the off gas treatment system could be sent off site for regeneration Spent ion exchange resin from the Building 891 water treatment system would continue to be regenerated on site

Cost

Costs for this alternative include the costs for the following items

- soil gas survey (approximately 100 probes)
- two groundwater extraction wells (six inch diameter, 20-foot depth)
- 15 vapor extraction wells (four-inch diameter, 20-foot depth)
- two vapor extraction systems, with blowers filters and other appurtenances
- activated carbon adsorption system (two vessels containing 1 500 pounds each)
- radio frequency heating unit
- associated piping, pumps, and instrumentation
- UV/peroxide/ion exchange water treatment system operation
- groundwater monitoring for 30 years

The capital cost for Alternative 5 is $1 845 700 O&M and post-closure activities for Alternative 5 includes operation of the enhanced SVE operation of the existing french drain and operation of the Building 891 water treatment system until the completion of remediation Groundwater monitoring for 30 years is also included The present worth of the O&M costs for this alternative is $3,845 700 the post-closure cost is $1 811,700 The total cost of this alternative is $7,503 100 A detailed cost estimate for capital and O&M costs for this alternative is included in Appendix E

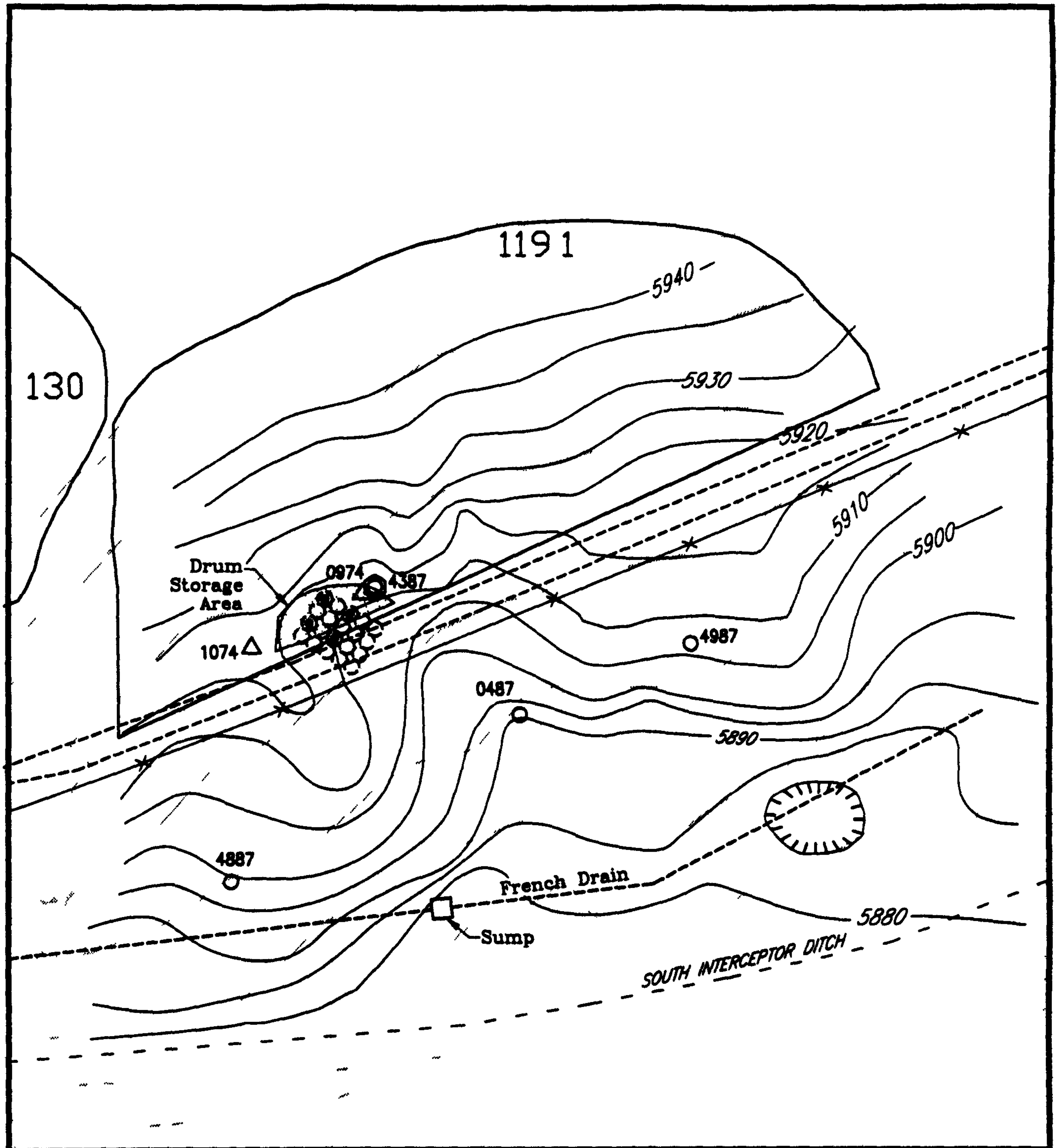
4 2 7 Alternative 6. Hot Air Injection With Mechanical Mixing

This alternative would remediate groundwater by pumping it to the surface and treating it in the Building 891 water treatment system It would also remove residual sources of contamination from the soil with a combination of in situ mechanical mixing and soil vapor extraction with hot air injection The alternative targets dissolved adsorbed vapor and free phase DNAPL contamination A detailed soil gas survey consisting of approximately 100 soil gas probes would be conducted initially to determine locations within the source area that require remediation

The treatment zone would initially be dewatered by pumping the existing groundwater extraction well This is expected to take approximately five days since the well is currently in operation and the water table in the vicinity is already depressed The area near the existing well would then be treated using a portable system that combines mechanical mixing and thermal enhancement with conventional SVE techniques This is an innovative propriety technology which increases the rate of soil vapor recovery through vigorous mixing and thermally enhanced volatilization The rig-mounted equipment consists of a 10-foot diameter auger capable of mixing soil to a depth of 20 feet while injecting hot air Soil vapors are recovered at the surface through a 12 foot diameter shroud The physical mixing ensures exposure of all treated soils to high volume air flow and eliminates channeling and dead zones The combination of mixing and enhanced volatilization reduces treatment time and increases contaminant removal effectiveness in heterogenous or tightly consolidated media such as is present at OU 1 A plan view of Alternative 6 is shown in Figure 4-2

As the system moves from one soil column to the next, groundwater extraction wells would be installed and removed from various locations in the treated unconsolidated material to ensure that the treatment zone is kept dewatered during treatment Several wells would be installed permanently as groundwater monitoring locations

The remedial time frame for this treatment method is highly dependent on site conditions and




EXPLANATION

104 INDIVIDUAL HAZARDOUS SUBSTANCE SITE

B301889 ALLUVIAL WELL

0271 PRE-1986 WELL

BH1587 BOREHOLE

10 DIAMETER BORE

GROUND WATER EXTRACTION WELL

5900 BEDROCK TOPOGRAPHY C.I. = 5'

TOPOGRAPHIC CONTOUR INTERVAL = 10 FEET

N

0 50 100

SCALE 1 100'

U S DEPARTMENT OF ENERGY

**Rocky Flats Environmental Technology Site**
**Golden Colorado**

**881 HILLSIDE AREA**
**OPERABLE UNIT NO 1**

**Plan View for Alternative #6**

**Figure 4-2**

OU1-BRS DWG

the volume of soil requiring remediation The system would operate for approximately three months and treat approximately 4 500 cubic yards of soil The french drain would be decommissioned upon completion of remedial activities

The evaluation of the two threshold and five balancing criteria for Alternative 6 Hot Air Injection With Mechanical Mixing are summarized as follows

Overall Protection of Human Health and the Environment

This alternative would be protective of human health and the environment by removing the contaminants from both groundwater and subsurface soils at IHSS 119 1 Exposure potential would be reduced by decreasing the contaminant concentrations and removing the source The existing french drain and extraction well would continue to capture contaminated groundwater and prevent downgradient migration of COCs

This alternative would be protective of the environment both downgradient of and within OU 1 because in addition to utilizing the existing french drain to intercept contaminated groundwater migrating away from OU 1, the source at IHSS 119 1 would be remediated

Hot air injection may have some negative impacts on the soils at OU 1 due to the high temperatures that are reached during operation While the elevated temperatures may increase the effectiveness of treatment for the COCs they may be harmful to subsurface biota This technology may also have a higher potential to spread the contaminants away from the treatment zone

Alternative 6 would meet key ARARs In particular MCLs would continue to be achieved for groundwater COCs at Woman Creek, providing long term effectiveness In addition this alternative would provide permanence to the degree that it could effectively treat the source area at IHSS 119 1 However, there is some uncertainty as to the level of cleanup that could be achieved for DNAPLs with this technology

Because this alternative would remediate the source at IHSS 119 1 modeling shows that a risk level of 3 22x10$^{7}$ would be achieved at Woman Creek respectively Therefore the magnitude of residual risk that would result from the implementation of this alternative falls well below the acceptable risk range of $10^{-4}$ to $10^{-6}$ Risk from surface soil contaminants would remain within the acceptable risk range of $10^{-4}$ to $10^{-6}$

This alternative would be completed in approximately one year During implementation there would be no unacceptable short term risks to the public There may be potential risks to on site workers from exposure to COCs in groundwater or soil vapor and safety hazards associated with construction activities the hot air injection and operation of the mechanical mixing tool However risks would be minimized through standard health and safety practices

Compliance With Applicable or Relevant and Appropriate Requirements

The designation of ARARs for this alternative is the same as has been presented in Alternative 4 and 5 Similarly, the compliance with these ARARs is the same that is Alternative 6 will comply with chemical-specific, action specific and location specific ARARs The following discussions mention the variations of technology and implementation where it is important to compliance with ARARs

Chemical Specific ARARs

The results of groundwater modeling and groundwater monitoring indicate that groundwater at Woman Creek currently meets MCLs Modeling results also indicate that there will be no exceedance of MCLs at Woman Creek through implementation of this alternative Groundwater modeling results demonstrate that the highest concentration of PCE period is 5 94x$10^{-4}$ mg/ℓ for this alternative The peak concentration occurs over a short duration and is below the MCL Assumptions of the model are discussed in Appendix B and have included factors for natural degradation but not volatilization of organics

## Action Specific ARARs

Compliance with the RCRA requirements for

- identification of hazardous waste treatment residuals (off gas treatment system)
- storage of hazardous waste treatment residuals
- disposal of hazardous waste treatment residuals
- organic air emission leaks from the treatment system
- a temporary unit
- a CAMU can be achieved with this alternative

The CDPHE would need to designate OU 1 a CAMU and establish the closure and any groundwater monitoring requirements in compliance with the RCRA regulations (6 CCR 1007 3) Alternative 6 similar to Alternative 5 may enhance the amount of organics that can be extracted from the soil and soil vapor, assuming mechanical mixing and hot air injection work effectively It is possible that these combined technologies will leave slightly less contaminants in the CAMU area at the time of closure than Alternative 4

Other action specific ARARs would be complied with in a manner similar to Alternative 4 and 5

## Location Specific ARARs

It is assumed that mechanical mixing hot air injection and additional extraction wells will be placed within or near IHSS 119 1, away from the french drain and Pond C 1 Therefore the habitat and fauna such as Preble s meadow jumping mouse will remain intact This species is of special concern not threatened or endangered, under State or Federal law It is anticipated that compliance with DOE wetland protection regulations and the State s law concerning non game species will be achieved with implementation of this alternative Should it be necessary riparian habitat would be replaced if it is destroyed by the thermal technology

Long Term Effectiveness and Permanence

This alternative would remediate the source area at IHSS 119 1 and the existing french drain extraction well and treatment system would continue to extract and treat contaminated groundwater migrating from IHSS 119 1 Therefore the residual risk would be reduced as compared to the no action and institutional control alternatives

This alternative may provide more effective and permanent treatment as compared to the SVE alternatives Alternatives 4 and 5, because mechanical mixing and hot air injection would more thoroughly remove residual COC concentrations from the soil There is some uncertainty however, that the COCs at IHSS 119 1 can be effectively remediated due to the low permeability of the soils and the general lack of documented experience in effective DNAPL treatment at any site If residual COCs are not effectively removed during remedial activities they may continue to act as a source of groundwater contamination

Following treatment of the source contaminated groundwater within OU-1 would continue to migrate away from IHSS 119 1 Modeling indicates that under this alternative groundwater would continue to meet MCLs for the COCs at Woman Creek A five year review would be conducted to determine the continued effectiveness of this alternative

This alternative would provide long-term protection for potential human receptors and minimize the human health risk associated with contaminated groundwater by continuing to achieve MCLs at Woman Creek However, although the MCLs can continue to be achieved with this alternative by remediating the soils and groundwater, this alternative may not be completely effective at removing DNAPLs if they are present at OU 1

Contaminated materials generated as a result of this alternative include spent carbon from the remediation equipment off-gas treatment system and spent ion exchange resins from the Building 891 water treatment system The spent GAC would be shipped off site for regeneration and the spent ion exchange resin could continue to be regenerated on site There are no significant risks associated with handling and shipping either the spent carbon or the ion exchange resins

Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 6 would satisfy the NCP preference for treatment as a principal element of the alternative This alternative would effectively reduce the mobility and volume of contaminants in OU 1 by removing any secondary source of contaminants from the subsurface Mechanical mixing and hot air injection would reduce the volume of COCs in subsurface soil in both the saturated and unsaturated zones Removing the residual sources of contaminants will also reduce their mobility by preventing potential additional migration

Extracted groundwater would be treated in the Building 891 water treatment system This is a destructive treatment process and thus would result in decreased toxicity GAC from the off gas treatment system would be regenerated, resulting in additional reductions in toxicity

The hot air injection and mechanical mixing technology utilizes soil vapor extraction to control COCs volatilized by the mixing and increased temperatures However the technology may actually increase the mobility of contaminants by spreading them beyond the boundaries of the treatment zone

Contaminated materials generated as a result of this alternative include activated carbon from remediation equipment off gas treatment system and spent ion exchange resins from the Building 891 water treatment system There are no significant risks associated with handling and shipping either the spent activated carbon or ion exchange resins

Short Term Effectiveness

This alternative would have significant short term impacts on the environment within the treatment zone at IHSS 119 1 Impacts include disturbance to the soil and displacement or loss of vegetation during remedial activities The hot air injection and thorough mechanical mixing would have severe impacts on subsurface biota due to the high temperatures that are reached during operation  Potential short term impacts to the public are minimal under this alternative

Potential risks to workers during remediation activities include potential exposures to COCs in extracted groundwater or in soil vapor  There are also safety hazards associated with the operation of the mechanical mixing equipment  Mixing the soil would increase the risks associated with operating heavy equipment in OU 1  which is characterized by highly unstable soils  The risks to workers would be minimized through standard construction and process equipment operation safety practices

Implementability

This alternative would be readily implementable  Although the technology that would be utilized in this alternative is not as common as those for the other remediation alternatives  equipment for hot air injection and mechanical mixing is readily available  The implementability of this alternative would not be limited by the availability of services and materials, nor would there be any significant administrative difficulties associated with this alternative

There are several potential technical problems that may be encountered if this alternative is implemented  First, the technology may be difficult to implement at OU 1 due to the claystone material that is found in the subsurface  The formation is highly unstable  which may present safety problems during remedial operations  In addition  as the remediation progresses the remediation zone would become completely mixed  saturated, and soft  Installing the necessary dewatering and monitoring wells into the treatment zone may not be possible if a drill rig can not be driven onto this material

Administrative requirements for this alternative would include obtaining an air emissions permit for the off gas system  Spent ion exchange resin from the Building 891 water treatment system could continue to be regenerated on site

Cost

Costs for this alternative include the costs for the following items

- soil gas survey (approximately 100 probes)
- five groundwater extraction wells (six inch diameter 20 foot depth)
- mechanical mixing unit
- associated piping pumps and instrumentation
- UV/peroxide/ion exchange water treatment system operation
- groundwater monitoring for 30 years

The capital cost for Alternative 6 is $1 354 400 O&M and post-closure activities for Alternative 6 include the operation of the existing french drain and Building 891 water treatment system until completion of remedial activities and groundwater monitoring for 30 years The present worth O&M cost for this alternative is $1 887 300 the post-closure cost is $1 789 100 The total cost of this alternative is $5 030 800 A detailed cost estimate for capital and O&M costs for this alternative is included in Appendix E

4 2 8 Alternative 7. Soil Excavation and Groundwater Removal With Sump Pumps

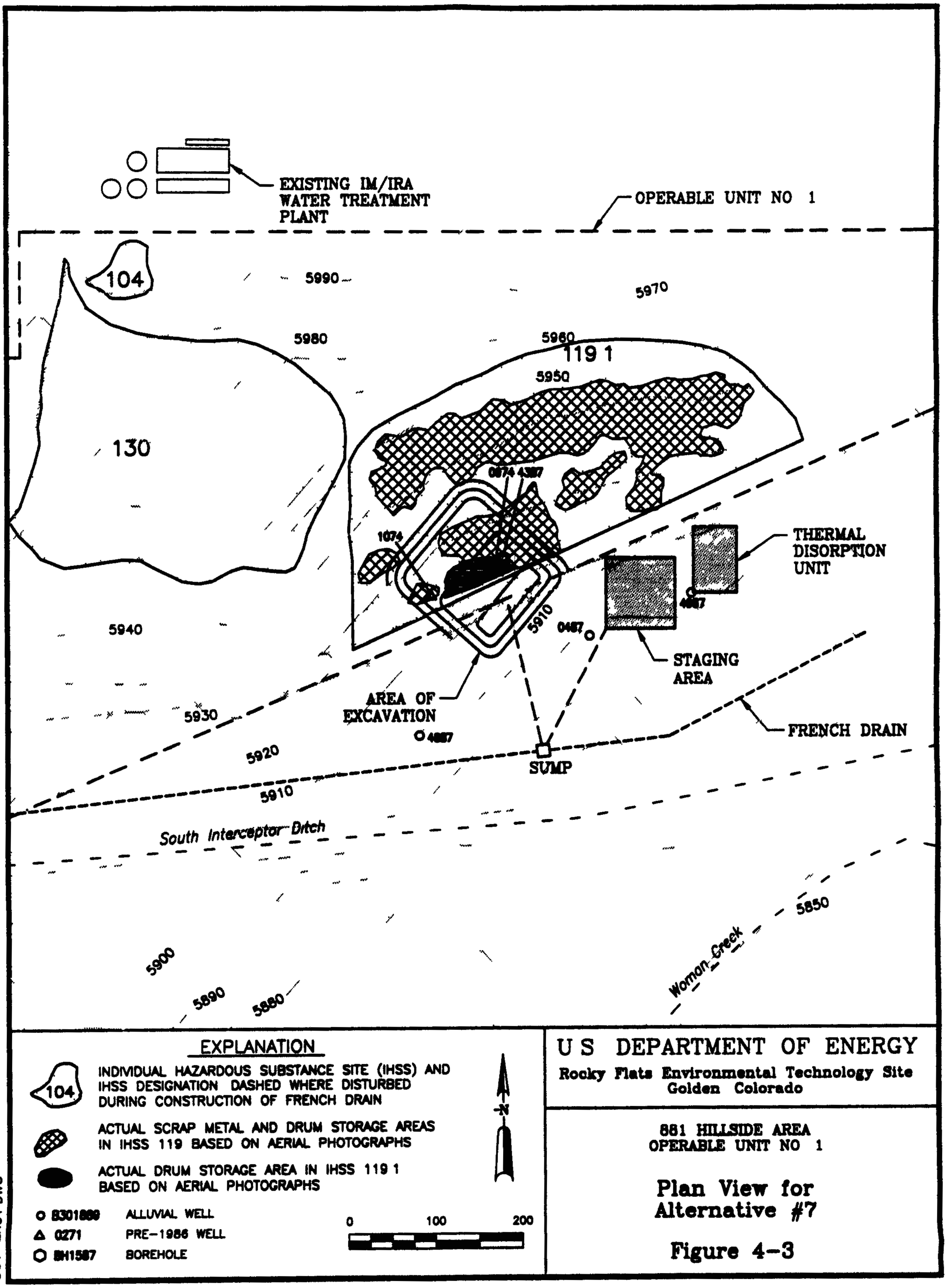
This alternative consists of the excavation of approximately 20 000 cubic yards of unsaturated and potentially saturated soil from IHSS 119 1 The amount of groundwater collected from dewatering the excavation would be approximately 80,000 gallons depending on the seasonal level of the water table Standard submersible pumps would be utilized to pump the groundwater to the OU 1 french drain sump pump which would then direct the water to the Building 891 water treatment system for final treatment and discharge

The top soil located within the excavation area would be scraped and stockpiled on site to be treated with top soils from OU 2 at a later time and the subsurface soils excavated and transported to a staging area constructed within 300 feet of the excavation The soil removed from the excavation could not be replaced because even treated soils could not be certain to be protective of groundwater MCLs The low organic carbon content of the soil favors partitioning to the aqueous phase, therefore very small concentrations of VOCs in soil could result in aqueous phase concentrations greater than the MCLs Based on a fraction of organic carbon ($f_{oc}$) of 0 002 for the soils at OU 1 (DOE 1994a) the concentrations of COCs in soil that would be required to be protective of groundwater MCLs are below detection limits and therefore too low to verify Therefore all excavated soils would need to be disposed off site Prior to being disposed in an off site hazardous waste landfill however the soil would require treatment to meet the Land Disposal Restriction treatment standards for each constituent The treatment standards for 1 1 DCE $CCl_4$ PCE and 1 1 1 TCA are 33 mg/kg (proposed) 5 6 mg/kg 5 6 mg/kg and 5 6 mg/kg respectively

The excavated soil stockpiled in the staging area would be dewatered and then treated by a skid mounted thermal desorption unit The duration of this alternative has been estimated to be nine months although it is highly dependent upon the capacity of the thermal desorption unit Radiological monitoring would be conducted for the duration of the alternative A plan view of Alternative 7 is illustrated in Figure 4-3

Thermal desorption is a commercially available proven technology for the removal of volatile organics from soil A conveyor feeds the soil to the thermal desorption unit which raises the temperature of the soil to 343 °C to volatilize the VOCs The thermal desorption unit would be equipped with a baghouse to remove any particulates from the exhaust stream and an off gas treatment unit such as a catalytic oxidizer, for the destruction of any remaining VOCs and carbon monoxide The treated air could then be emitted to the atmosphere A thermal desorption unit could be obtained locally and mobilized on site in one day

Following treatment, the soil would be packaged and shipped to a licensed facility located within 100 miles of the site It should be noted that there is currently a proposed rule which states that if the soil were to be treated to meet the proposed Universal Treatment Standard for each contaminant of concern it may be possible to put the soil back into the excavation following treatment However given the geology of the site there is a possibility that the soils treated to either of these standards could contaminate the groundwater above MCLs if it were placed


EXISTING IM/IRA WATER TREATMENT PLANT
OPERABLE UNIT NO 1
104
130
119 1
5990
5980
5970
5960
5950
5940
5930
5920
5910
5900
5890
5880
5850
1074
THERMAL DISORPTION UNIT
STAGING AREA
AREA OF EXCAVATION
SUMP
FRENCH DRAIN
South Interceptor Ditch
Woman Creek
EXPLANATION
INDIVIDUAL HAZARDOUS SUBSTANCE SITE (IHSS) AND IHSS DESIGNATION DASHED WHERE DISTURBED DURING CONSTRUCTION OF FRENCH DRAIN
ACTUAL SCRAP METAL AND DRUM STORAGE AREAS IN IHSS 119 BASED ON AERIAL PHOTOGRAPHS
ACTUAL DRUM STORAGE AREA IN IHSS 119 1 BASED ON AERIAL PHOTOGRAPHS
ALLUVIAL WELL
0271 PRE-1986 WELL
BOREHOLE
N
0
100
200
U S DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden Colorado
881 HILLSIDE AREA
OPERABLE UNIT NO 1
Plan View for Alternative #7
Figure 4-3

OU1-EXC1 DWG

back into the excavation It has therefore been assumed that the soil would require shipment to an off site disposal facility

Extensive groundwater monitoring would not be required for this alternative because the source of contamination would be removed Groundwater monitoring would be continued to evaluate the effectiveness of the removal action Short term air monitoring would be required during excavation activities The french drain would be decommissioned upon completion of remedial activities

The evaluation of the two threshold and five balancing criteria for Alternative 7 Soil Excavation and Groundwater Removal With Sump Pumps are summarized as follows

<u>Overall Protection of Human Health and the Environment</u>

This alternative would be protective of human health and the environment by excavating and treating subsurface soils, and pumping and treating groundwater at IHSS 119 1 Exposure potential would be reduced by decreasing the contaminant concentrations and removing the source The existing french drain and extraction well would continue to capture contaminated groundwater and prevent downgradient migration of COCs

This alternative would be protective of the environment both downgradient of and within OU 1 because in addition utilizing the existing french drain to intercept contaminated groundwater migrating away from OU 1, the source at IHSS 119 1 would be remediated

This alternative would meet key ARARs In particular, MCLs would continue to be achieved for groundwater COCs at Woman Creek, providing long-term effectiveness This alternative would also provide the greatest degree of permanence of all the treatment alternatives because excavating the source area would be the most effective way to remove DNAPLs

Alternative 7 would have a significant impact on the environment due to the large excavation and matenal transportation requirements Excavating the entire source area would negatively impact the flora and subsurface biota However there are no significant long term effects anticipated from this alternative

Because this alternative would remediate the source at IHSS 119 1 a risk level of 3 $22\times10^{-7}$ would be achieved at Woman Creek respectively Therefore the magnitude of residual risk that would result from the implementation of this alternative falls well below the acceptable risk range of $10^{-4}$ to $10^{-6}$ Additionally risk from surface soil contaminants would remain within the acceptable risk range of $10^{-4}$ to $10^{-6}$

This alternative would be completed within one year During implementation there would be the potential for risk to the public due to potentially contaminated air borne dust generated during excavating activities and the transportation of large quantities of excavated soils off site There may also be potential risks to workers from exposure to COCs in groundwater or air borne dust Workers would also have potential safety hazards associated with operating the earth-moving equipment and the thermal desorption unit However risks to workers would be minimized through standard health and safety practices

Compliance With Applicable or Relevant and Appropriate Requirements

The ARARs associated with this alternative are very similar to those presented and discussed for Alternatives 4 5 and 6 Alternative 7 can comply with chemical-specific location specific and action specific ARARs The major difference of this alternative from 4, 5 and 6 is the excavation of soil to groundwater the subsequent aboveground treatment of soils and disposal of soils in a RCRA facility The management of soils will require compliance with the hazardous waste land disposal restrictions The following paragraphs summarize the compliance with ARARs status for this alternative

Chemical Specific ARARs

The results of groundwater modeling and groundwater monitoring indicate that groundwater at Woman Creek currently meets MCLs  Modeling results also indicate that there will be no exceedance of MCLs at Woman Creek through implementation of this alternative  Groundwater modeling results demonstrate that the highest concentration of PCE is 5 94x$10^{4}$ mg/$\ell$ for this alternative  The peak concentration occurs over a short duration and is below the MCL  Assumptions of the model are discussed in Appendix B and have included factors for natural degradation but not volatilization of organics

Action Specific ARARs

Compliance with the following RCRA requirements will be accomplished

- identification of hazardous waste treatment residuals
- treatment of contaminated soil in a temporary unit
- disposal of hazardous waste treatment residuals and soil
- monitoring of organic air emission equipment leaks and process vents
- a CAMU for OU 1

Although the source of the majority of contamination would be removed with this alternative because some unknown amount contamination would be left in place  CDPHE would need to designate OU 1 as a CAMU  It is anticipated that once groundwater is removed and treated in the Building 891 water treatment system  and soil is treated and disposed of off site  the requirements for groundwater monitoring and post-closure of the CAMU could be minimal

It is possible that EPA s proposed definition of soil contaminated with hazardous waste could be promulgated prior to the final CAD/ROD  It is anticipated that this alternative would meet the proposed changes to the definition of hazardous waste

Other action specific ARARs such as Regulation 7  Control of VOC Emissions of the Colorado air pollution regulations, will be complied with in operating the desorption unit  Levels of emissions are anticipated to be below two tons/year of VOCs

Location Specific ARARs

This alternative would involve placement of a PVC pipe from the excavated area of contamination to the existing french drain sump Although the area involved in construction activity would be small, there would be a short term impact to riparian/wetland areas around the french drain Any riparian vegetation which is destroyed would be replaced according to DOE regulations on wetland protection This assumes it is determined that there are no other alternatives which could achieve the same or similar result

This alternative could result in a negative short term impact to a State species of special concern Mitigation measures would need to be discussed within the State Division of Wildlife to enable the least disruption to habitat and compliance with the State law on protection of species of special concern, such as Preble s meadow jumping mouse

Long Term Effectiveness and Permanence

This alternative would remove contaminated groundwater and soil including the residual concentrations and any non aqueous phase that may act as a source thereby significantly reducing potential risks to human health and the environment The existing french drain extraction well and Building 891 water treatment system would continue to extract and treat contaminated groundwater migrating from IHSS 119 1 until the concentrations of COCs in groundwater at OU 1 are reduced below MCLs Therefore, the residual risk would be reduced as compared to the no action and institutional controls alternatives

Following treatment of the source, contaminated groundwater within OU 1 would continue to migrate away from IHSS 119 1 Modeling indicates that under this alternative groundwater would continue to meet MCLs for the COCs at Woman Creek A five-year review would be conducted to determine the continued effectiveness of this alternative

This alternative would provide long term protection for potential human receptors and minimize the human health risk associated with contaminated groundwater by continuing to achieve MCLs at Woman Creek However although the MCLs can be achieved with this alternative by remediating the soils and groundwater this alternative may not be effective at removing DNAPLs if they are present at OU 1 outside the area to be excavated

Excavated soils would be treated on site by thermal desorption and shipped for off site disposal at a properly permitted facility There are no significant risks associated with handling and shipping the treated soils

Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 7 satisfies the NCP preference for treatment as a principal element of the alternative This alternative would effectively and irreversibly reduce the mobility and volume of contaminants in OU-1 by removing any secondary source of contaminants from the subsurface Excavating the soils within the treatment zone would reduce the volume of COCs in subsurface soils in both the saturated and unsaturated zones Dewatering the excavation during remediation would likewise reduce COC volumes in groundwater Removing the residual sources of contaminants will also reduce their mobility by preventing potential additional migration

COC-contaminated soils removed from the excavation would be treated using thermal desorption This would reduce the volume and toxicity of COCs in soils prior to off site disposal at a properly permitted facility In addition extracted groundwater would be treated in the Building 891 water treatment system, which is a destructive treatment process and thus would result in a further decrease in toxicity

Contaminated materials generated as a result of this alternative include spent ion exchange resins from the Building 891 water treatment system and treated soils excavated from the treatment zone There are no significant risks associated with handling and shipping either the ion exchange resins or the treated soils

Short Term Effectiveness

This alternative would have significant short term impacts on the environment within the treatment zone at IHSS 119 1 Short term impacts to human health and the environment associated with this alternative include potential worker and public health exposure to airborne dust created during excavation and the displacement or loss of vegetation

Alternative 7 would have a significant short term impact on the environment due to the large excavation and material transportation requirements Excavating the entire source area would negatively impact the site flora as well as subsurface biota

During implementation there would be the potential for risk to the public due to potentially contaminated air borne dust generated during excavating activities and the transportation of large quantities of excavated soils off site There may also be potential risks to workers from exposure to COCs in groundwater or air borne dust Workers would also have potential safety hazards associated with operating the earth-moving equipment and the thermal desorption unit However risks to workers would be minimized through standard health and safety practices

Implementability

Excavation would be implemented using standard earth-moving equipment However, the potential for radionuclide contamination in the excavated soils may limit the ability to transfer the soils off site A large area would be required for stockpiling and treating the excavated soils, however, there is sufficient space available adjacent to the area to be excavated

Excavated soils would be treated by thermal desorption a proven and commonly applied soil remediation technology The implementability of this alternative would not be limited by the availability of services and materials, nor would there be any significant technical or administrative difficulties associated with this alternative Groundwater monitoring would be used to determine the effectiveness of this alternative

Cost

Costs for this alternative include the costs for the following items

- Conventional excavation/backfill earth moving equipment
- UV/peroxide/ion exchange water treatment system operation
- Thermal desorption unit
- Disposal of treated soil at licensed facility
- Associated piping, pumps and materials
- Groundwater monitoring for 30 years

The capital cost for Alternative 7 is $11 326,100 O&M and post-closure activities for Alternative 7 include groundwater monitoring for 30 years The present worth O&M cost for this alternative is $0 the post-closure cost is $1,767,600 The total cost of this alternative is $13 093 700 This cost estimate does not include the cost for disposal of radionuclide contaminated soil, if any is encountered A detailed cost estimate for capital and O&M costs for this alternative is included in Appendix E

## 4 3 Comparative Analysis of Alternatives

This section presents the comparative analysis which assesses the relative performance of each alternative in relation to each specific evaluation criteria excluding the two modifying criteria (state and EPA acceptance and community acceptance) The comparative analysis is summarized in Table 4-1

### 4 3 1 Overall Protection of Human Health and the Environment

All of the seven remedial action alternatives proposed meet key ARARs at OU-1 Specifically under each alternative groundwater would continue to meet the MCL for PCE the indicator chemical at Woman Creek Other contaminants appear in orders of magnitude lower concentrations (see Appendix B) All of the remedial action alternatives also satisfy the criterion of overall protection of human health and the environment by continuing to achieve groundwater MCLs at Woman Creek for the COCs identified at OU 1 For all alternatives risk levels for a receptor at Woman Creek would be less than $2 \times 10^{-6}$ Alternatives 0 1 2 and 3 would each satisfy the criterion although they do not address the source area at IHSS 119 1 Treatment alternatives 4 5 6 and 7 would likewise satisfy the criterion although to a greater extent

Alternative 0 No Action would result in the highest risk of all the alternatives although this risk ($2 \times 10^{-6}$) is still within the established protective risk range of $10^{-4}$ to $10^{-6}$ Alternative 1 would not present any human health risk because the entire RFETS site would be restricted under this scenario thus eliminating the potential for exposure Alternatives 2 and 3 would have the next lowest risk for a receptor at the edge of the operable unit these two alternatives involve the continued operation of the existing french drain and extraction well and result in a risk of $4\ 76 \times 10^{-9}$ at Woman Creek The four alternatives that address the source at IHSS 119 1 Alternatives 4, 5, 6, and 7, have slightly higher risk levels because under these alternatives the french drain is decommissioned as soon as the source is remediated, allowing low concentrations of contaminants to continue migrating away from OU 1 However these concentrations drop off rapidly after remediation is complete and result in lower long term risks to human receptors $3\ 22 \times 10^{-7}$

To the extent that COCs would be removed and treated Alternatives 2 3 4 5 6 and 7 would all provide some degree of permanence However, the source treatment alternatives (4, 5 6 and 7) would be more effective in the long term Alternative 7 which would remove the source by excavation would provide the most permanence because of the uncertainty associated with the other alternatives ability to effectively remove DNAPLs

There would be no significant increase in potential risks to the public under Alternatives 0 1 2 3 4 5 or 6 Alternative 7, however would increase the risks to the public due to the potentially COC-contaminated dust that could become airborne during excavation activities and off site transportation of excavated soils

There would be no significant risks to on site workers under any of the alternatives These risks would be minimized through standard health and safety practices Alternatives 5 6 and 7 would have the most significant impacts on the environment due to in situ heating mixing and excavation all of which are disruptive to the subsurface

Under this criterion the alternatives are ranked as follows

| Rank | Alt. # |
|---|---|
| 1 | 2 3 |
| 2 | 7 |
| 3 | 4 5 6 |
| 4 | 0 1 |

4 3 2 Compliance with Applicable or Relevant and Appropriate Requirements

All alternatives would comply with the chemical specific action specific and location specific ARARs identified for OU 1 Compliance with the action specific ARARs specifically state RCRA regulations depends on CDPHE designating the OU 1 area a CAMU under Subpart S of the hazardous waste management regulations (6 CCR 1007 3 264 552) The closure post closure and groundwater monitoring requirements would be specified in the designation according to the selected alternative Remediated waste including groundwater and soil contaminated with hazardous waste constituents is allowed to be left in place at the time of closure of the unit under the CAMU rule, providing certain provisions of the regulations are complied with and a determination is made that in taking such action there would not be risks to human health or the environment Since all the alternatives meet the MCLs at Woman Creek other differences in compliance with the ARARs are presented There are possibly two differences in how some of the alternatives comply with the CAMU rule the State Non game Endangered or Threatened Species Conservation Act and DOE regulations on compliance with wetlands protection

Under this criterion the alternatives are ranked as follows

| Rank | Alt. # |
|---|---|
| 1 | 4 5,6 7 |
| 2 | 2 3 |
| 3 | 0 1 |

4 3 4 Reduction of Toxicity, Mobility, and Volume Through Treatment

Alternatives 0 and 1 which would not continue to operate the french drain or remediate the source would not reduce either toxicity mobility or volume of contaminants through treatment Alternative 2 and 3 would reduce the volume of contaminants and prevent migration of contaminants away from the operable unit by continuing to operate the existing french drain and extraction well These alternatives would also reduce toxicity by treating extracted groundwater with through the existing UV/peroxide/ion exchange process (Building 891 water treatment system)

Alternatives 4 5 6 and 7 would reduce the toxicity mobility and volume of contaminants further and more rapidly than the no action and institutional control alternatives because they would treat the source area at IHSS 119 1 Alternative 5 enhanced SVE would reduce volume and mobility more effectively than Alternative 4, SVE without subsurface heating Alternative 6 hot air injection and mechanical mixing, would reduce toxicity, mobility, and volume more effectively than Alternative 5 and Alternative 7 excavation would still more effectively reduce contaminant toxicity, mobility, and volume

Under this criterion the alternatives are ranked as follows

| Rank | Alt. # |
|---|---|
| 1 | 4 5 6 7 |
| 2 | 2 3 |
| 3 | 0 1 |

4 3 5 Short Term Effectiveness

Alternative 0 which would include only groundwater monitoring would not create any short term risks for the local community or the environment Likewise Alternative 1 which only includes institutional controls in addition to monitoring would not create any short term risks Alternatives 2 and 3 which would continue to operate the existing french drain and extraction well would not create any additional risks to the community or the environment as compared to the existing conditions at OU 1

Alternatives 4 5 6 and 7, which would remediate the source area at IHSS 119 1 would not create any significant potential for risk to the local community with the exception of Alternative 7 which may generate dust during excavation due to the large quantities of soil to be moved Under Alternative 7 there would also be risks associated with transporting the large quantities of excavated soils off site Each of the source remediation alternatives would present potential risks to workers during construction and operation however, these risks would be minimized through standard health and safety practices Alternative 4 would have minor impacts on the environment Alternatives 5 and 6 would have significant short-term impacts on the environment due to subsurface heating which may have adverse effects on biota In addition Alternative 6 would thoroughly mix the soil, increasing the impact on the subsurface environment Alternative 7 would also have significant impacts on the environment because a large volume of soil would completely removed

Under this criterion, the alternatives are ranked as follows

| Rank | Alt. # |
|---|---|
| 1 | 0 1,2 |
| 2 | 3 |
| 3 | 4 5 6 |
| 4 | 7 |

4 3 6 Implementability

Alternative 0 would be the most readily implementable alternative because it requires only groundwater monitoring Alternative 1 would require institutional controls over the entire RFETS site such as designating the site a wildlife refuge and this could present some administrative problems although it effectively represents current conditions Alternatives 2 and 3 the other institutional controls alternatives, would be readily implementable as compared to Alternative 1 and the other treatment alternatives

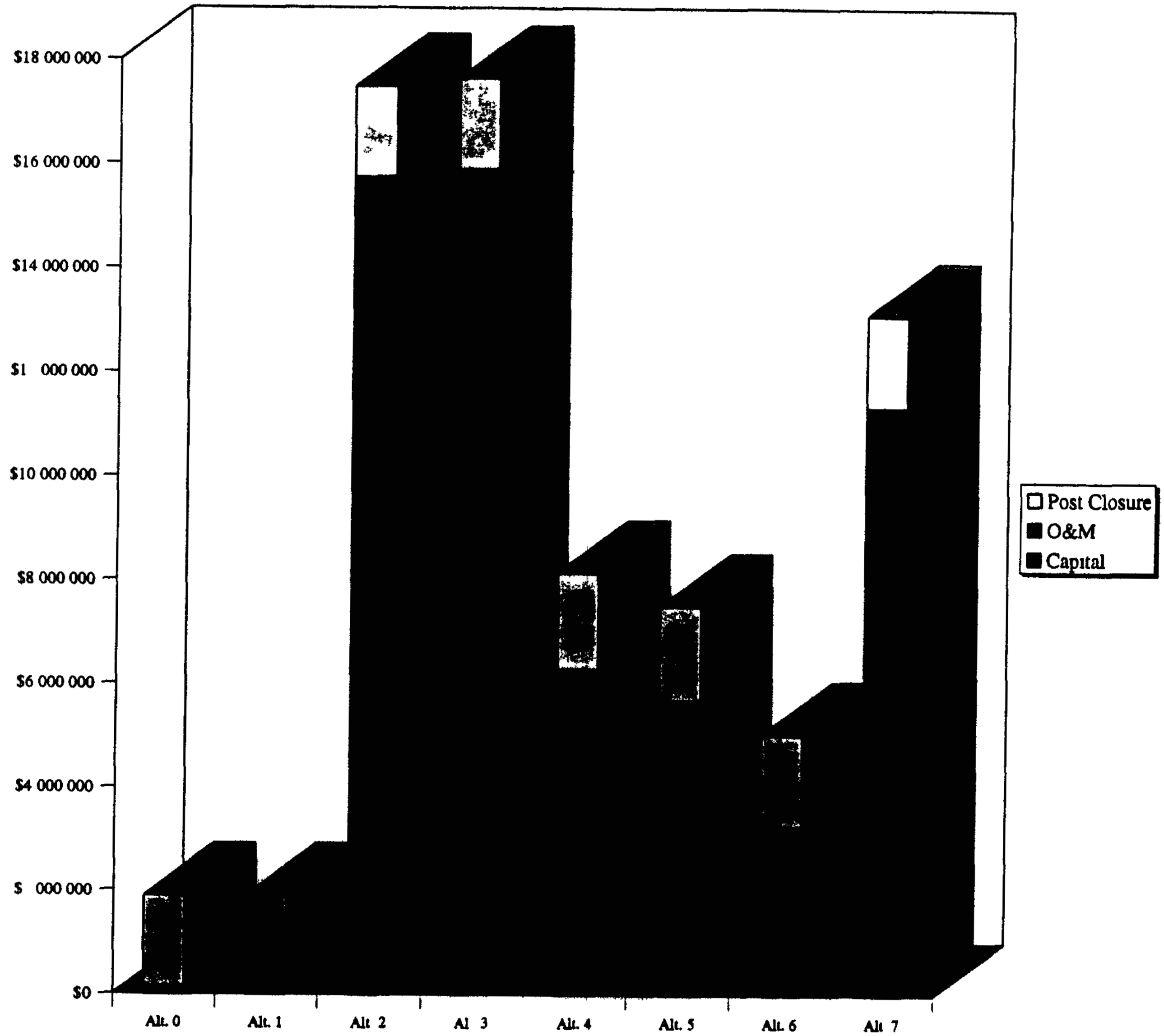
Alternatives 4 and 5 would also be readily implementable with no significant technical or administrative difficulties anticipated However Alternative 6 may be difficult to implement because of the instability of the subsurface soils within the treatment zone Alternative 7 which would require large quantities of soil stockpiled and treated on site, and then transported off site for ultimate disposal would also be more difficult to implement

Under this criterion, the alternatives are ranked as follows

| Rank | Alt. # |
|---|---|
| 1 | 2 |
| 2 | 0 1 |
| 3 | 3 |
| 4 | 4,5,6 |
| 5 | 7 |

4 3 7 Cost

Figure 4-4 presents a comparison of the costs for the seven remedial alternatives Alternatives 0 and 1 are the least costly alternatives because they involve only the continuation of groundwater monitoring Alternatives 2 and 3 are significantly more costly than the other alternatives including the source treatment alternatives (4 5 6 and 7) due to the cost of operating the Building 891 water treatment system for 30 years Of the four source treatment alternatives Alternative 7 has the highest cost due to the need to treat the excavated soils to




| Cost Element | Alt 0 | Alt 1 | Alt 2 | Alt 3 | Alt 4 | Alt 5 | Alt 6 | Alt 7 |
|---|---|---|---|---|---|---|---|---|
| Capital | $154 700 | $154 700 | $149 600 | $305 000 | $929 300 | $1 845 700 | $1 354 400 | $11 326 100 |
| O&M | $0 | $0 | $15 603 300 | $15 603 300 | $5 358 700 | $3 845 700 | $1 887 300 | $0 |
| Post Closure | $1 740 400 | $1 740 400 | $1 740 400 | $1 740 400 | $1 853 800 | $1 811 700 | $1 789 100 | $1 767 600 |
| Total Cost | $1 895 100 | $1 895 100 | $17 493 300 | $17 648 700 | $8 141 800 | $7 503 100 | $5 030 800 | $13 093 700 |

Note Co ts represent 1994 dollars at 5% discount rate

**Figure 4 4 Summary of Remedial Action Alternative Costs**

meet Land Disposal Restriction treatment standards and dispose of them at an off site hazardous waste landfill

Under this criterion, the alternatives are ranked as follows

| Rank | Alt. # |
|---|---|
| 1 | 0 1 |
| 2 | 6 |
| 3 | 4,5 |
| 4 | 7 |
| 5 | 2,3 |

4 4 Preferred Remedial Action Alternative

Based on the results of the comparative analysis of alternatives, **Alternative 1 Institutional Controls without the French Drain** is selected as the preferred remedial action alternative for OU-1 This alternative is intended to minimize the risk from contaminated groundwater in OU 1 by restricting access to any wells impacted by OU-1 contaminants, and by eliminating the possibility of building construction above areas known to be contaminated with VOCs This alternative would be implemented by maintaining the current institutional controls present at the RFETS to at a minimum the Woman Creek drainage

4 4 1 Description

This alternative assumes that the existing french drain system would not be actively pumped but instead would be maintained and monitored as a contingency, in case groundwater contaminant concentrations begin exceeding predicted values If this occurs, water collected in the french drain sumps would be pumped to the Building 891 water treatment system The alternative cost estimate includes decommissioning the drain because it is assumed that at some point the drain will no longer be required

Groundwater monitoring would be required for this alternative to determine when institutional controls could be discontinued Once acceptable groundwater contaminant concentrations are achieved through natural degradation and dispersion of contaminants the area would be released from institutional controls Groundwater monitoring would take place for as long as required to meet this criterion It is assumed that six monitoring points would be sufficient under this alternative For cost estimating purposes it is assumed that four new wells would be installed one deep and shallow well cluster downgradient of IHSS 119 1 and possibly two additional wells upgradient of Woman Creek Samples would also be collected from the french drain sump and from the existing recovery well Samples would be analyzed for organic and inorganic contaminants and would be collected semiannually Analysis of individual species of inorganic contaminants is also suggested, to identify individual metal species which have the potential to bioaccumulate This additional analysis requirement should only be applied occasionally in the sampling program PQLs for analysis of these samples would be established to meet CDPHE criteria

### 4 4 2 Summary of Detailed Analysis

This alternative would be protective of human health assuming that the institutional controls are properly implemented and that the site is not abandoned during the institutional control period The risk to human receptors is 1 $99 \times 10^{-6}$ at Woman Creek Risks from surface soils at OU 1 are within the acceptable risk range of $10^{-4}$ to $10^{-6}$ Likewise environmental receptors would be protected because there is no current or future risk identified from groundwater COCs for these receptors There are no potential short term risks to the public or to on-site workers identified through implementation of this alternative

Under this alternative the french drain would not be used to actively remediate contaminated groundwater, however concentrations of contaminants in downgradient groundwater would gradually be reduced over time due to natural physical and chemical processes, such as dispersion volatilization and biodegradation Because these are natural processes they are essentially irreversible and would effectively reduce the toxicity mobility and volume of contaminants permanently

This alternative is the most implementable of all alternatives identified because it utilizes the existing controls present at the RFETS  Costs associated with this alternative are similar to the no action alternative, and are lower than all other alternatives

Key ARARs would be met under this alternative  The results of groundwater monitoring and modeling indicate that groundwater at Woman Creek currently does not exceed MCLs  Modeled contaminant concentrations projected 400 years from 1969 also indicate that there will be no exceedance of MCLs at Woman Creek within the 400-year period  Groundwater modeling results demonstrate that the highest concentration of PCE (the indicator COC) during the 400-year period is $3\ 60 \times 10^{-3}$ mg/$\ell$ under this alternative  Other COCs in OU-1 result in significantly lower concentrations at Woman Creek (see Appendix B)  These results are considered extremely conservative due to the assumptions used to develop the model  The model assumes an infinite source of contamination and does not account for volatilization of contaminants, a potentially significant loss mechanism  Appendix B includes details concerning the groundwater model

Alternative 1 will meet substantive requirements of the State RCRA program assuming CDPHE staff designates the OU-1 area as a CAMU under the recently adopted Subpart S provisions (6 CCR 1007 3  Part 264, Section 552)  The CDPHE is required to determine that the unit will facilitate implementation of a reliable, effective, protective, and cost-effective remedy  In addition  CDPHE can require closure, post-closure  and any groundwater monitoring determined necessary to detect direction and movement of hazardous constituents  This report provides documentation to meet CAMU requirements  and to suggest an appropriate monitoring program The final CAD/ROD document will incorporate public comments and will provide all necessary documentation required by the CAMU rule regarding public participation

In summary  Alternative 1 is protective of human health and the environment at minimal additional expense  The alternative will comply with identified ARARs  and will be effective in reducing contaminant concentrations through natural processes  The alternative provides for natural attenuation with minimal additional impacts  Due to the limited availability of groundwater in the saturated zone beneath OU 1 this alternative presents the most cost-effective and practical remediation alternative for OU 1 groundwater

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# APPENDIX A

# INITITAL SCREENING AND EVALUATION OF TECHNOLOGIES AND PROCESS OPTIONS

# A 1 0 INTRODUCTION

The purpose of this appendix is to summarize the initial screening and evaluation of technologies and process options for the RFETS OU 1 CMS/FS This screening and evaluation was presented in detail in *Technical Memorandum #11 Development and Screening of Remedial Action Alternatives 881 Hillside Area (OU 1) (April 1994)* The screening and evaluation matrices for the groundwater medium are presented

Additionally although radionuclide contamination in surface soils has been included within the scope of the OU 2 CMS/FS, technology identification and screening of remedial technologies were performed prior to the determination to include OU 1 surface soil radionuclides in the larger OU 2 contamination plume Work completed to date on identification screening and evaluation of technologies appropriate for contaminants identified in OU 1 surface soils is also presented through the attached figures

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SCREENING COMMENT |
|---|---|---|---|---|
| No Action | None | Not applicable | Required for consideration by the National Oil and Hazardous Substances Contingency Plan | Potentially applicabl as baseline against which other GRAs/alternatives can be compared during detailed analysis |
| | Monitoring | Groundwater Monitoring | Monitoring of groundwater in operable unit during and after remediation, or as part of an institutional control period associated with the No Action alternative | Potentially applicable for monitoring site-specific groundwater conditions |
| Institutional Controls | Access Restrictions | Legal restrictions on access | Restrictions on present and future access to land prevent unauthorized access to groundwater source | Potentially applicabl for controlling access to groundwater sources and/or exposure to COCs |
| | | Fencing or other physical barriers | Fencing, security posts, limited roads and other various physical restrictions limit access to groundwater sources | Potentially applicable for controlling access to groundwater sources and/or exposure to COCs |
| | | Legal restrictions on land use | Restrictions on present and future use and/or purchase of land; includes actions such as zoning and deed restrictions | Potentially applicabl for controlling use of land affected by contaminated groundwater zones |

Doubl lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability applicability or feasibility

**Figure A 1 Initial Screening of Technologies and Process Options for Groundwater**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SCREENING COMMENT |
|---|---|---|---|---|
| Containment | Vertical Subsurface Flow Control | Subsurface Drains | Gravity driven collection system which is used to redirect groundwater flow and/or collect it for treatment | Potentially applicable includes possibi ty of modifying existing french drain system for se during remediation |
| | | Grout Curtains | Grout columns" are injected vertically into the soil in close proximity of each other to form an impermeable wall | Would not contribut additional ontainment becau of existing low hydraulic onductivity |
| | | Slurry Walls | A soil/bentonite or cement grout wall formed by backfilling a trenched area, has a lower permeability than native soils | Not implementable because of hillsid tability concern trenching may lead to slumping of native soils |
| | | Sheet Pilings | Steel forms which are driven into the ground and joined to form a barrier which is impermeable to groundwater | Very difficult to implement due to proximity of bedrock not widely used or accepted in cleanups |
| | | Cryogenic Barrier | A section of ground is frozen to reduce its permeability thus limiting the mobility of contaminants through the area | Only applicabl as a short term measure to control the migration of contaminants through an area |
| | Horizontal Subsurface Flow Control | Grout Injection | Grout is injected in a horizontal pattern beneath surface soils to limit vertical migration of VOCs from groundwater | Not applicable for remediation of VOCs in groundwater in fractured bedrock |
| | | Block Displacement | Innovative use of grout forms perimeter barrier around waste while displacing waste upwards to block pathway | Not applicabl for ontrol of VOC that esult from volatilization of groundwater contaminants nor for use in fractured bedrock |
| | Vapor Containment | Surface Cap | Compacted soil and bentonit cap used to reduce water infiltration to subsurface, and to contain VOC emissions | Potentially applicabl for reducing vapor phase transport to surface structures |
| | | Environmental Isolation Enclosure | One of several types of temporary structures used to contain/collect fugitive vapors and dust during remedial action activities, utilizes additional off-gas treatment | Potentially applicabl for scenarios which would involve excavating soil to reach groundwater |

Doubl lines surrounding process option or technology denote options that were screened out from further consideration on the basis of technical implementability applicability or feasibility

**Figure A 1 Initial Screening of Technologies and Process Options for Groundwater (Cont )**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SCREENING COMMENT |
|---|---|---|---|---|
| Removal | Passive Removal | Subsurface Drains | Gravity driven collection system which i used to redirect groundwater flow and/or collect it for treatment | Potentially applicable includes possibility of modifying existing french drain system for use during remediation |
| | Active Removal | Horizontal and/or Vertical Extraction Wells or Sumps | Systems consisting of well installed either vertically or horizontally that are used to collect/recharge groundwater | Potentially applicable for removing ontaminated water for treatment, for diverting groundwater flow or for lowering localized water tabl |
| | Excavation | Loader/Excavator/Dozer | Tractor/wheel mounted vehicles commonly used to excavate or move large amounts of soil can operate at various depths | Potentially applicable for removal of subsurfac soil to locate groundwater hotspots |
| In-Situ T eatment of Chlorinated Solvents | Biological | Bioremediation | Destroy organics through microbial degradation methanotropic process is specific to chlorinated solvents | Potentially applicabl for in situ treatment of organi compounds in groundwater however degradation products may be more harmful than original contaminants |
| | Chemical | Polymerization | Catalyst injected into groundwater causes polymerization of organic monomers forming a gel-like, non-mobile mass | Contact between reagent and groundwater is eventually overly hindered by the formation of the gel-lik mass |
| | | Chemical Oxidation | Breakdown of organics using chemical which are typically introduced into the subsurface via injection wells or by drilling directly into the edge or within contaminant plume | Difficult to apply because of concerns over injecting additional chemical into the subsurface which may result in the formation of hazardous oxidation product |
| | Physical | Hot Air/Steam Stripping with Mechanical Mixing | Hot air or steam is injected into the groundwater to promote the volatilization of VOCs which have low vapor pressures | Potentially applicabl to remove VOC which are less likely to be volatilized through conventional means |
| | | Air Sparging | Pressurized air is injected below or within a contaminated groundwater plume to cause in situ stripping of VOCs | Potentially applicabl for in situ treatment of VOCs in groundwater |
| | | Vapor Extraction | Induced negative pressure above saturated zone collects volatilized contaminants for treatment | Potentially applicabl for removal of VOC from groundwater or for supporting other technologies ( g air sparging) |
| | | Permeable Treatment Beds | A fixed bed containing treatment resins is placed down-gradient of a groundwater plume to treat water in situ | Potentially applicabl for in situ treatment of organi compounds in groundwater (incl ding VOC in vados zone) however limited by site hydrogeology |
| | | In Situ Adsorption w/Wells (proprietary process) | Adsorption of organic contaminants in groundwater through the use of proprietary resin beads placed in existing well | Potentially applicable for in situ treatment of organ compounds in groundwater (including VOC in dos zone) but not implementabl due to low hydraulic conductivity |
| | | RF/Ohmic Heating | Contaminants olatilized and/or destroyed by energy ab orbed from radio frequency or ohmic sources | Potentially applicabl for in situ treatment of organi compounds effectiveness not dependent on ond ctivity or presence of groundwater |

Doubl lines surrounding process option or technology denot option that were screened out from further consideration on the basis of technical implementability applicability or feasibility

**Figure A 1 Initial Screening of Technologies and Process Options for Groundwater (Cont )**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SCREENING COMMENT |
|---|---|---|---|---|
| Ex Situ Treatment of Chlorinated Solvents | Biological | Bioremediation | Destroy organics through microbial degradation methanotropic process is specific to chlorinated solvents | Potentially applicable for ex situ treatment of organic compounds in groundwater however degradation products may be more harmful than original contaminants |
| | Chemical | Solvent Extraction | Removal of organics by mass transfer to an organic solvent which is mutually insoluble with the original solvent (water) | Not feasible for groundwater with low VOCs concentrations solvent would still require treatment/disposal |
| | | Ultraviolet Photolysis with Chemical Oxidation | UV radiation is applied to assist in oxidizing organic compounds using various oxidizing agents thereby destroying them | Potentially applicabl for destroying organic compounds in extracted groundwater may include modification of existing UV/peroxide treatment system |
| | Physical | Gamma Irradiation | Innovative technology which decomposes organic compounds by destroying their chemical bonds using gamma irradiation | Not widely documented as to its use in the treatment of organic wastes also not feasible for low contaminant levels |
| | | Activated Carbon or Carbonaceous Adsorbents | Extracted groundwater is passed through activated carbon which adsorbs most of the organic contaminants | Potentially applicable for removing organ compounds from extracted groundwater carbon could be disposed of or regenerated |
| | | Air Stripping | Water is sprayed through a packed tower designed to increase its surface area to air ratio, thereby promoting volatilization | Potentially applicable for removing volatil organics compounds from extracted groundwater |
| | | Membrane Processes | Application of an osmotic" pressure forces contaminants to flow through semi-permeable membrane against diffusion | Not directly applicabl for treatment of VOC in ground-water more commonly used to remove particulates |
| | | Hot Air/Steam Stripping | Similar to air stripping but uses hot air or steam to remove VOCs which have relatively low vapor pressures | Potentially applicable for removing volatil organic compounds from extracted groundwater |
| | | Evaporation | Concentration method used to drive off solvent from an aqueous waste stream using man-made and/or natural means | Not applicable as a stand-alone treatment technology more often used as pre-treatment step for a process |
| | | Freeze Crystallization | Method of removing dissolved organic species by freezing the supporting matrix and crystallizing the solvent for separation | Only feasible for aqueous waste streams where organic contaminant concentrations are above 3 7 % by weight |
| | Thermal | Incineration | Destruction of organics through combustion with oxygen using a thermal and/or catalytic process option | Generally not applicable for liquids treatment at low contaminant concentration level |
| | | Plasma Arc Discharge | Pyrolysis of organics by high temperature plasma induced through electrical discharge to carrier gas | Potentially applicable for destruction of refractory oragnics in extracted groundwater |
| | | Catalytic Oxidation | Catalyst allows low temperature thermal degradation of halogenated hydrocarbons to carbon dioxide water and hydrogen chloride. Also destroys non-halogenated VOCs forming water and carbon dioxide | Potentially applicable for treatment of groundwater or air Can produce acid off-gas |

Double lines surrounding a process option or technology denote option that were screened out from further consideration on the basis of technical implementability applicability or feasibility

**Figure A 1 Initial Screening of Technologies and Process Options for Groundwater (Cont )**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SCREENING COMMENT |
|---|---|---|---|---|
| In-Situ Treatment of Inorganics | Physical | Electrokinesis | Electrodes are inserted in boreholes and a current passed through the media, causing migration of ions to the oppositely charged electrode wher they are extracted by conventional pumping | Potentially applicabl for the removal of metal from contaminated groundwater |
| Ex-Situ Treatment of Inorganic | Physical | TRU Clear (Proprietary Process) | A proprietary potassium ferrate solution is mixed with groundwater precipitating transuranic and heavy metals | Potentially applicabl for treatment of extracted groundwater currently undergoing treatability studies at RFP |
| | | Oxidation/Reduction | Chemicals are added to groundwater which alter the oxidation state of the metals, causing precipitation | Potentially applicabl for treatment of extracted groundwater however limited by low treatment efficiency |
| | | Ferrite Process | Ferrite particles sorb metals and precipitate out of solution | Potentially applicable for treatment of extracted groundwater similar to TRU-Clear process mentioned above |
| | | Magnetic Separation | A high gradient magnetic field is applied to groundwater which forces polar metal ions out of solution onto collector plates | Conceivably applicable for treatment of extracted groundwater however not an established technology for groundwater treatment |
| | Chemical | Freeze Crystallization | Contaminated solution is evaporated to saturation and then crystallization is induced by heat removal | Not feasible for waste stream with low ontamnant concentrations due to prohibitive energy costs |
| | | Ion Exchange | Metal species exchanged for resin ions and bound onto ion exchange resin for disposal | Potentially applicabl for treatment of some metal however not applicable to many metal species |
| | | Evaporation | Contaminated waste volume reduced by evaporation of solution in which contaminants are dissolved/suspended | Not feasibl for extracted OU1 groundwater due to prohibitive energy costs |
| | | Membrane Processes | Metals concentrated by passing the contaminated solution through a semi-permeable membrane | Potentially applicable for treatment of extracted groundwater however may have prohibitive energy costs |
| | | Electrocoagulation | Neutralization and precipitation of metallic ions is induced by creation of neutralizing ions using electrical current | Potentially applicable for treatment of extracted groundwater |
| | | Precipitation | Removal of inorganics from aqueous phase by changing oxidation state through addition of chemicals or energy | Potentially applicabl for removal of ingorganics from xtracted groundwater however difficult t ontrol for omplex wast streams |

Doubl lines surrounding process option or technology denote options that were screened out from further consideration on the basis of technical implementability applicability or feasibility

**Figure A 1 Initial Screening of Technologies and Process Options for Groundwater (Cont )**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | EFFECTIVENESS | IMPLEMENTABILITY | RELATIVE COST |
|---|---|---|---|---|---|
| No Action | None | Not applicable | May not achieve remedial action objectives although required for consideration by NCP | Difficult to implement if public oncern is high regarding site conditions | Very Low Capital<br>Very Low O & M |
| | Monitoring | Groundwater monitoring | Effective in monitoring site conditions, or with No Action alternative as an institutional control | Readily implementabl depending on remedial alternative selected | Low Capital<br>Low O & M |
| Institutional Controls | Access Restrictions | Legal restrictions on access | Effective for relatively short-term control of present and future access to groundwater | Difficulty in obtaining necessary legal restrictions may reduce implementability | Low Capital<br>Very Low O & M |
| | | Fencing or other physical barriers | Moderately effective for relatively short term control of present and future access to area | Readily implementabl if area under consideration is already site property | Moderate Capital<br>Low O & M |
| | | Legal restrictions on land use | Effective for control of present and future use of land which is affected by remedial actions | Difficulty in obtaining necessary legal restrictions may reduce implementability | Low Capital<br>Very Low O & M |
| Containment | Vertical Subsurface Flow Control | Subsurface Drains | Effective in diverting flow of groundwater around targeted areas to limit the mobility of contaminants | May be difficult to implement upgradient of plume due to proximity of buildings | Moderate Capital<br>Low O & M |
| | Vapor Containment | Surface Cap | Effective in dispersing vapor plume and reducing localized atmospheric emissions | Readily implementabl using common construction equipment | High Capital<br>Moderate O & M |
| | | Environmental Isolation Enclosure | Effective in preventing the inadvertent release of VOCs and dusts during remediation | Readily implementabl with many vendors available as suppliers | Moderate Capital<br>Low O & M |
| Removal | Passive Removal | Subsurface Drains | Effective in collecting ground water if the ystem is designed appropriately for site conditions | Modification of existing french drain would be readily implementable if required | Moderate Capital<br>Very Low O & M |
| | Active Removal | Horizontal and/or Vertical Extraction Well or Sumps | Effective in diverting collecting or recharging groundwater when gradient is relatively flat | Readily implementabl based on existing site conditions if few well are involved | Low Capital<br>Low O & M |
| | Excavation | Loader/Excavator/Dozer | Tractor/wheel mounted ehicles commonly used to excavate or move larg amounts of soil can operat t various depths | Readily implementabl although may b limited by bedrock formations | Low Capital<br>Moderate O & M |

**Figure A 2 Evaluation of Process Options for Groundwater**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | EFFECTIVENESS | IMPLEMENTABILITY | RELATIVE COST |
|---|---|---|---|---|---|
| In-Situ Treatment of Chlorinated Solvents | Biological | Bioremediation | Effective in treating organics but difficult to monitor progress during in situ treatment; may result in residuals which require further treatment | Requires extensive treatability work t determine viability of microbial growth for existing site-specific condition | Moderate Capital Moderate O & M |
| | Physical | Hot Air/Steam Stripping with Mechanical Mixing | Most effective in removing VOCs and SVOCs from groundwater but air/steam must b collected | Innovative technology which is onsidered moderately difficult to implement | High Capital High O & M |
| | | Air Sparging | Effective in removing volatile organics and volatile inorganics from groundwater in situ | Requires horizontal drilling below water table so air will reach contaminant areas | Moderate Capital Moderate O & M |
| | | Vapor Extraction | Moderately effective in removing VOCs from saturated soils although limited by nature of contamination | Would require the use of extraction wells to temporarily depress the water tabl | Low Capital Moderate O & M |
| | | RF/Ohmic Heating | Effective in removing organics from ground-water but off-gas collection and treatment required | Treatability studies required to optimize frequency and phase settings for RFP | Moderate Capital Moderate O & M |
| Ex Situ Treatment of Chlorinated Solvents | Biological | Bioremediation | Effective in treating organics but may possibly result in residuals which require further treatment | Readily implementabl if all contaminants can be degraded under similar condition | Moderate Capital Moderate O & M |
| | Chemical | Ultraviolet Photolysis with Chemical Oxidation | Effective and proven method of destroying organic contaminants in extracted groundwater | UV treatment system already exists on site and may be used w/o significant modification | High Capital High O & M |
| | Physical | Activated Carbon or Carbonaceous Adsorbents | Effective if used as a final polishing step in a groundwater treatment system | Readily implementabl as this is a common technology supported by many vendors | Moderate Capital Moderate O & M |
| | | Air Stripping | Effective in removing VOCs and some SVOCs from extracted groundwater in large volumes | Readily implementabl as this is common technology supported by many endors | Low Capital Moderat O & M |
| | | Hot Air/Steam Stripping | Effective in removing VOCs and some SVOCs from extracted groundwater | Readily implementabl but more difficult than air stripping due to addition of steam | Moderate Capital Moderate O & M |
| | Thermal | Plasma Arc Discharge | Effective in destroying organics including refractory halogenated compounds | Treatability studies required to optimize energy level and treatment times for RFP | High Capital Moderate O & M |
| | | Catalytic Oxidation | Effective in destroying organics including refractory halogenated compounds | Treatability studies required to determine catalyst, temperature and residence time | High Capital Moderat O & M |

**Figure A 2 Evaluation of Process Options for Groundwater (Cont.)**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | EFFECTIVENESS | IMPLEMENTABILITY | RELATIVE COST |
|---|---|---|---|---|---|
| In-Situ Treatment of Inorganics | Pysical | Electrokinesis | Effective in removing ionic inorganic species from groundwater but unproven for most inorganics | Requires extensive treatability studies to determine applicability to site contaminants | Moderat Capital<br>High O & M |
| Ex-Situ Treatment of Inorganics | Physical | TRU Clear (Proprietary Process) | Effective in removal of inorganic species from extracted groundwater to extremely low levels | Use of proprietary chemical vailable from single vendor may limit implementability | Moderate Capital<br>Moderate O & M |
| | | Oxidation/Reduction | Effective in precipitating many inorganics, however is difficult to control for multiple species | Treatability studies required to determine reagents required for site contaminants | Low Capital<br>Moderate O & M |
| | | Ferrite Process | Effective in removal of metal and radionuclides from extracted groundwater by precipitation | Readily implementable sing commonly available equipment and chemicals | Low Capital<br>Moderate O & M |
| | Chemical | Ion Exchange | Effective in removing virtually all inorganics from water however may require extensive pretreatment | Treatment system already exists on site and may be used w/o significant modification | Moderate Capital<br>Low O & M |
| | | Membrane Processes | Effective in removing many inorganics from water however may require extensive pretreatment | Implementability may be limited by influent water quality and low COC concentrations | Moderate Capital<br>High O & M |
| | | Electrocoagulation | Effective in removing most inorganic ions from water however it is nonselective process | Extensive treatability studies required due to innovative status of technology | Moderate Capital<br>High O & M |
| | | Precipitation | Effective in removing most inorganic ions from water however it is a nonselective process | Treatability studies required to determine chemicals which best address site conditions | Moderate Capital<br>High O & M |

**Figure A 2 Evaluation of Process Options for Groundwater (Cont.)**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SCREENING COMMENT |
|---|---|---|---|---|
| No Action | Non | Not applicabl | Required for consideration by NCP | Potentially appl cable as a compan on against other GRAs |
| Institutional Control | Monitoring | Long-term surface soil and air monitoring | Monitonng of site conditions within operabl unit after remediation or as part of an institutional control period associated with the no-action alternative | Potentially applicabl for monitonng site-specific surface soil conditions (i e. fugitive dust monitonng) |
| | | Short-term surface soil and air monitoring | Monitoring of site conditions within operabl unit during remediation activities | Potentially applicable for monitoring site-specific surface soil condition (i e. fugitive dust monitoring) |
| | Access Restrictions | Legal restrictions on access | Restrictions on present and future access to land prevent unauthorized access to contaminated areas | Potentially applicable for controlling access to areas which are subject to dust emissions or surface contamination |
| | | Fencing or other physical barriers | Fencing, security posts limited roads and other various physical restrictions limit access to contaminated areas | Potentially applicabl for controlling access to areas which are subject to dust emissions or surface contamination |
| | | Legal restrictions on land use | Restrictions on present and future use and/or purchase of land· includes actions such as zoning and deed restrictions | Potentially applicable for controlling use of land which may be contaminated or subject to hazardous dust emissions |

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability applicability or feasibility

**Figure A 3 Initial Screening of Technologies and Process Options for Soils**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SCREENING COMMENT |
|---|---|---|---|---|
| Containment | Capping | Chemical Sealant | Chemical stabilizers are mixed with surface soil to form a stabilized cover which is resistant to water infiltration | Not applicabl for remediation due to limitations on design lif not widely sed or epted in cleanup |
| | | Clay / Soil Cap | Compacted soil and bentonite ( g bentomat liner) cap used to reduce water infiltration and to mitigate erosion and dust hazards | Potentially applicabl to prevent contact with surfac soil which may be ontaminated and to contain them in situ |
| | | Cement based Cap | Concrete slab over area of concern minimizes water infiltration and mitigates erosion and dust hazards | Would not b appropriate for scal required and would not provide additional protection beyond other cap types |
| | | Asphalt based Cap | Asphalt cover over area of concern minimizes water infiltration and mitigates erosion and dust hazards | Would not b appropriate for scal required and would not provide additional protection beyond other cap types |
| | | Synthetic Cap | Flexible liner used as sole cover source to reduce water infiltration to subsurface, and to prevent dust emissions | Not applicable for remediation due to limitation on design life; not widely used or accepted in cleanup |
| | | Multimedia Cap | EPA recommended cap design which contains several layers (e.g. clay geomembrane, soil vegetative) minimizes water infiltration, erosion and dust emissions | Potentially applicable to prevent contact with surface soil which may be contaminated and to contain them in situ |
| | Erosion Control | Diversion / Runoff Control | Surface water routing measures that seek to redirect flow to minimize erosion of soil and spreading of contaminants | Not considered necessary because operable unit topography currently provides for sufficient runon/runoff control |
| | | Wind Breaks | Mesh-like barriers used to reduce wind speeds over small areas to minimize erosion of soils and reduce dust emissions | Potentially applicabl to reduce erosion rate and for dust control however wind breaks would not be considered a permanent solution |
| | | Surface Armoring | Surface soils are held in place by covering with riprap or other debris, minimizes wind and water effects | Potentially applicabl to reduce erosion if nprap does not interfere with remedial alternative selected |
| | | Vegetation | Natural vegetation is used to provide firm upper soil layer to limit dust emissions and surface water effects on soils | Potentially applicable as natural method for erosion control may be implemented during remediation |

Doubl lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability applicability or feasibility

**Figure A-3 Initial Screening of Technologies and Process Options for Soils (Cont )**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SCREENING COMMENT |
|---|---|---|---|---|
| Removal / Disposal | Excavation | Loader / Excavator / Dozer | Tractor/wheel mounted vehicles commonly used to excavate or move large amounts of soil can operate at various depths | Potentially appl cabl for excavation of surfac and subsurfac soil |
| | | Pneumatic | Vacuum extraction method for removal of loose dry surface soils or pumpable liquids into tank trucks or storage containers | Potentially applicabl for excavation of surface soil not applicable to subsurface soil |
| | Dust Control | Dust Suppressants | Various synthetic and natural compounds which are sprayed on surface soils to reduce fugitive dust emissions (e.g water) | Potentially applicabl to reduce dust emission during remediation of operable unit |
| | | Temporary Structures | Light, easily constructed structures used during remediation that provide protection from the effects of wind and rain | Not feasible because of areal extent of ontamination and not considered necessary for low levels of contamination |
| | | Geotextile Cover | Flexible geotextile membranes that can be used during remediation to cover surface soils and reduce dust emissions | Applicability is limited because of possibility that cover would interfere with process equipment and personnel |
| | On-Site Disposal | Engineered On-Site Disposal Facility | On-site disposal facility designed to contain site-specific waste for a single operable unit or for the entire site | Potentially applicabl for storage of contaminated surface and subsurface soil or residuals which result from the treatment of soil |
| | Off-Site Disposal | Permitted Off Site Disposal Facility | Existing facility which is permitted to accept operable unit-specific waste or remedial action waste treatment residual | Potentially applicabl for storage of contaminated surface and subsurface soils or residuals which result from the treatment of soil |

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basis of technical implementability applicability or feasibility

**Figure A 3 Initial Screening of Technologies and Process Options for Soils (Cont.)**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SCREENING COMMENT |
|---|---|---|---|---|
| In-Situ Treatment of PAHs and PCBs | Biological | Bioremediation | Destroys organics through microbial degradation several methods are available for treatment of PAH s | Feasibility limited for treating PAH in surfac soil du to very slow degradation rates and difficulty in process control |
| | Chemical | Chemical Oxidation/ Reduction | Breakdown of PAH s using chemical which are typically introduced into the subsurface via injection wells or by spraying directly over the surface soil requiring treatment | Difficult to apply because of concerns over injecting additional chemicals into the surface soil which may result in the formation of hazardou reaction products |
| | Physical | Soil Flushing | Aqueous flushing agents are forced through soils via injection wells which flush contaminants into a collection system | Not feasible for large areas which require shallow soil treatment |
| | | Vitrification | Electrical soil melting process that destroys most organics while containing other contaminants in a solid, glassy matrix | Applicability is limited by stability of hillside also not appropriate for low level of surface soil contamination |
| | | Radio Frequency Heating w/ Vacuum Extraction | Radio frequency energy is applied via electrodes to heat surrounding soils thereby promoting volatilization of PAH s | Not feasible for large areas which require shallow soils treatment |
| | | Shallow Soil Mixing | Upper layer of surface soils are mixed with lower layers to reduce contaminant exposure to erosion problems | Potentially applicable for surfac soils to limit the mobility of contaminants although may not prevent volatilization |
| | | Vacuum Extraction | A vacuum is applied to subsurface soils to volatilize organics and remove inorganics that are in the vapor phase | Not applicable for removal of PAH s from soil in situ PAH s do not volatilize significantly at normal temperatures |
| | | Hot Air/Steam Stripping | Hot air or steam is injected below surface soil to force organic contaminants to the surface for capture and treatment of semi-volatile contaminants | Not feasibl due to difficulty in sufficiently superheating steam to ensure adequate temperatures for volatilization of semi-volatile ontaminants |

Double lines surrounding a process option or technology denote options that were screened out from further consideration on the basi of technical implementability applicability or feasibility

**Figure A 3 Initial Screening of Technologies and Process Options for Soils (Cont )**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SCREENING COMMENT |
|---|---|---|---|---|
| Ex-Situ Treatment of PAHs and PCBs | Biological | Bioremediation | Destroys organics through microbial degradation several methods are available for treatment of PAH s | Potentially applicable for treating PAH in exca ated soil although limited by slow degradation rate |
| | | Land Application | Application of a thin layer of waste over an area to promote natural biodegradation may include addition of nutrients | Not implementable becaus of possibl radionuclide contamination in soil which would be spread during treatment |
| | Chemical | Ultraviolet Photolysis w/ Chemical Oxidation | UV radiation is applied to assist in oxidizing organic compounds (using various oxidizing agents) thereby destroying them | Potentially applicable for destroying PAH in excavated soils many aromatic reactions are UV (free radical) catalyzed |
| | | Solvent Extraction | Removal of organic compounds from soil by mass transfer to an organic solvent which is then collected and treated | Limited feasibility for removing PAH from soil with low contaminant concentrations, solvent would still require treatment/disposal |
| | Physical | Soil Washing | A variety of cleansing agents can be used to "wash" soil of organic contaminants, soils can be replaced after treatment | Potentially applicabl for removing organic compounds from soil although agent would still require treatment/disposal |
| | | Stabilization / Solidification | Binding agents are mixed with contaminated soils in either batch or continuous process to stabilize/solidify contaminants | Not appropriate for very low level of contamination especially for contaminants with low initial mobility |
| | | Incineration | Destruction of organics through oxidation and/or pyrolysis Various methods are available (i e. rotary kiln fluidized bed) | Potentially applicable for treatment of PAH and PCBs in surface soil although may not reach PRG target level |
| | | Thermal Desorption | Organics are volatilized from soil through the addition of heat; catalysts may be used to enhance process | Potentially applicabl for treatment of PAH s and PCBs in surface soil although may not reach PRG target levels |
| | | Virification | Electrical soil melting process that destroys most organics while containing other contaminants in solid glassy matrix | Potentially applicabl for treatment of excavated soil but may not be appropriate for low level of contamination |
| | | Molten Salt / Sodium Fluxing | Molten salt, air and soil are combined in a reactor to destroy organics through oxidation and to trap halogens | Not applicabl for treatment of PAHs more commonly used for remediating chlorinated sol ent ontamination |

Double lines surrounding process option or technology denote options that were screened out from further consideration on the basis of technical implementability applicability or feasibility

**Figure A 3 Initial Screening of Technologies and Process Options for Soils (Cont.)**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | DESCRIPTION | SCREENING COMMENT |
|---|---|---|---|---|
| In-Situ Treatment of Radionuclides | Physical | Soil Flushing | Complexing or chelating agents are sed to solubilize radionuclides and then extracting the contaminated flushing solution | Difficult to apply becaus of oncern over solubilizing radionuclides which could then migrate toward groundwater |
| | | Stabilization / Solidification | Binding agents are injected into contaminated soils and then harden to stabilize/solidify contaminants | Difficult to implement due to large surface area and minimal depth of contamination |
| | | Shallow Soil Mixing | Upper layer of surface soils are mixed with lower layers to reduce contaminant exposure to erosion problems | Potentially applicable for surfac soil to limit the mobility of contaminants and to reduce potential human exposure level |
| | Thermal | Vitrification | Electrical soil melting process that encapsulates radionuclides and other contaminants in solid, glassy matrix | Applicability is limited by stability of hillside also not appropriate for low levels of surface soil contamination or large, shallow areas |
| Ex-Situ Treatment of Radionuclides | Physical | Soil Washing | A variety of cleansing agents can be used to "wash soil of radionuclides, soils can be replaced after treatment | Potentially applicabl for excavated surfac soil although "wash" solution would require additional treatment/disposal |
| | | Stabilization / Solidification | Binding agents are mixed with contaminated soils in either a batch or continuous process to stabilize/solidify contaminants | Potentially applicabl for excavated surface soils contaminated with radionuclides |
| | | Manganese Dioxide Adsorption | Radionuclides are adsorbed from slurried soil onto manganese dioxide particles | Not feasible due to its experimental nature and the extent of research and treatability studies it would require; thus it has been screened out from RFP Sitewide treatability studies |
| | | Magnetic Separation | A high gradient magnetic field is applied to slurried soil which forces polar radioncuclides out of slurry onto collector plates | Potentially applicabl for excavated surface soil currently undergoing treatability studies at the Los Alamos National Laboratory |
| | | TRU-Clean (proprietary process) | Radionuclides are "washed" from slurried soils by a proprietary precipitation process | Potentially applicable for excavated surfac soils currently undergoing treatability studies at the Nevada Test Site |
| | | Segmented Gate System | Radioactive particles above threshold activities are removed from soil and concentrated by diversion gates attached to radiation monitors | Potentially applicabl for exca ated surface soil May exhibit low treatment efficiency on fine well distributed radiation sources such as those t OU1 |
| | Thermal | Vitrification | Electrical soil melting process that encapsulates radionuclides and other contaminants in solid glassy matrix | Potentially applicabl for excavated surfac soil contaminated with radionucl des |

Double lines surrounding process option or technology denote options that were screened out from further consideration on the basis of technical implementability applicability or feasibility

**Figure A 3 Initial Screening of Technologies and Process Options for Soils (Cont )**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | EFFECTIVENESS | IMPLEMENTABILITY | RELATIVE COST |
|---|---|---|---|---|---|
| No Action | None | Not applicable | May not achieve remedial action objectives although required for consideration by NCP | Difficult to implement if public concern is high regarding site conditions | Very Low Capital<br>Very Low O & M |
| Institutional Controls | Monitoring | Long-term surface soil and air monitoring | Effective in monitoring long-term site conditions after remediation, or as part of no-action alt. | Readily implementable depending on remedial alternative selected | Low Capital<br>Low O & M |
| | | Short-term surface soil and air monitoring | Effective in monitoring short-term site conditions to protect worker and public health and safety | Readily implementable depending on remedial alternative selected | Low Capital<br>Very Low O & M |
| | Access Restrictions | Legal restrictions on access | Effective for relatively short-term control of present and future access to designated area | Difficulty in obtaining necessary legal restrictions may reduce implementability | Low Capital<br>Very Low O & M |
| | | Fencing or other physical barriers | Moderately effective for relatively short-term control of present and future access to area | Readily implementable if area under consideration is already site property | High Capital<br>Low O & M |
| | | Legal restrictions on land use | Effective for control of present and future use of land which is affected by remedial actions | Difficulty in obtaining necessary legal restrictions may reduce implementability | Low Capital<br>Very Low O & M |
| Containment | Capping | Clay / Soil Cap | Moderately effective in preventing precipitation from reaching and mobilizing contaminated areas | Easiest to implement relative to other types of caps/covers available | Moderate Capital<br>Moderate O & M |
| | | Multimedia Cap | Most effective form of cap which is resistant to weathering and cracking over its design life | Moderately difficult to implement based on variety of materials required | High Capital<br>Very Low O & M |
| | Erosion Control | Wind Breaks | Marginally effective in reducing dust emissions or erosion over large areas of soil | Readily implementable does not require subcontractor support | Low Capital<br>Low O & M |
| | | Surface Armoring | Effective in reducing soil erosion caused by wind and precipitation also minimizes dust | Readily implementable if local supply of riprap or debris is available | High Capital<br>Very Low O & M |
| | | Vegetation | Effective in reducing soil erosion due to wind and precipitation if vegetation is maintained | Readily implementable requires common landscaping equipment available locally | Moderate Capital<br>Moderate O & M |

**Figure A-4 Evaluation of Process Options for Soils**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | EFFECTIVENESS | IMPLEMENTABILITY | RELATIVE COST |
|---|---|---|---|---|---|
| Removal / Disposal | Excavation | Loader / Excavator / Dozer | Effective for excavating soils and sludges less than 30 feet deep | Readily implementable uses common road building and construction equipment | Low Capital<br>Moderate O & M |
| | | Pneumatic | Effective in removing loose dry soils or pumpable liquids from ground surfaces and surface waters | Readily implementable | Low Capital<br>Low O & M |
| | Dust Control | Dust Suppressants | Moderately effective for reducing surface dust generation depending on type of suppressant | Readily implementable although certain suppressants may be considered hazardous | Low Capital<br>Moderate O & M |
| | On-Site Disposal | Engineered On-Site Disposal Facility | Effective in containing treated or residual wastes assuming the facility is designed properly | Difficult to implement because of permit requirements and administrative concerns | Very High Capital<br>High O & M |
| | Off-Site Disposal | Permitted Off-Site Disposal Facility | Effective in containing treated or residual wastes if proper facility is available | Readily implementable for wastes other than TRU or mixed (radioactive/hazardous) | Moderate Capital<br>Very Low O & M |

**Figure A-4 Evaluation of Process Options for Soils (Cont.)**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | EFFECTIVENESS | IMPLEMENTABILITY | RELATIVE COST |
|---|---|---|---|---|---|
| In-Situ Treatment of PAHs and PCBs | Biological | Bioremediation | Effective in treating organics but difficult to monitor progress during in situ treatment; may result in residuals which require further treatment | Requires extensive treatability work to determine viability of microbial growth | Moderate Capital<br>Moderate O & M |
| | Physical | Shallow Soil Mixing | Effective in treating upper soil layers in situ to prevent migration of contaminants | Readily implementable uses commonly vailable agricultural engineering equipment | Low Capital<br>Moderate O & M |
| Ex-Situ Treatment of PAHs and PCBs | Biological | Bioremediation | Effective in treating organics but may possibly result in residuals which require further treatment | Requires extensive treatability work to determine viability of microbial growth | Moderate Capital<br>Moderate O & M |
| | Chemical | Ultraviolet Photolysis w/Chemical Oxidation | Effective method for destroying some organic compounds depending on UV lamp used in system | Implementability will depend on oxidation method chosen to accompany UV process | High Capital<br>High O & M |
| | | Solvent Extraction | Effective in removing volatile and non-volatile organic compounds from soils although spent solvent will require treatment or disposal | Moderately difficult to implement relative to other ex situ treatment options | High Capital<br>Moderate O & M |
| | Physical | Soil Washing | Effective for removal of organic and inorganic contaminants; several washing agents available | Implementable technology which is based on commonly used ore mining technologies | High Capital<br>Moderate O & M |
| | | Incineration | Effective in destroying or removing organic contaminants to levels in the low ppm range | Implementable technology which has been used extensively for treating organics | High Capital<br>High O & M |
| | | Thermal Desorption | Effective for removing volatile and semi-volatile compounds from soil requires off-gas treatment | Implementable technology which has been used extensively for treating organics | High Capital<br>High O & M |
| | | Vitrification | Very effective for destroying organic waste while containing other contaminants such as metals | Innovative technology which is difficult to implement based on the complexity of equipment required to vitrify waste | Very High Capital<br>Very High O & M |

**Figure A-4 Evaluation of Process Options for Soils (Cont.)**

| GENERAL RESPONSE ACTION | REMEDIAL TECHNOLOGY | PROCESS OPTION | EFFECTIVENESS | IMPLEMENTABILITY | RELATIVE COST |
|---|---|---|---|---|---|
| In-Situ Treatment of Radionuclides | Physical | Soil Flushing | Innovative technology which is effective for removing certain radionuclides from soil particles | Moderately difficult to implement; requires system to collect and treat flushing agent | High Capital<br>Moderate O & M |
| | | Shallow Soil Mixing | Effective in stabilizing upper layer of soils in situ to prevent migration/contact with radionuclides | Readily implementable uses commonly available construction equipment | High Capital<br>High O & M |
| Ex-Situ Treatment of Radionuclides | Physical | Soil Washing | Effective for removal of radionuclides from soil if proper washing agents are used in the process | Implementable technology which is based on commonly used ore mining technologies | High Capital<br>Moderate O & M |
| | | Stabilization/ Solidification | Effective in containing radionuclides by containing them in a stabilized or solidified matrix | Moderately difficult to implement because of problems with long-term leach resistance | Moderate Capital<br>Moderate O & M |
| | | Magnetic Separation | Effective for removing trace amounts of metals from liquid waste streams, including radionuclides | Moderately difficult to implement | Moderate Capital<br>Moderate O & M |
| | | TRU-Clean (proprietary process) | Innovative proprietary process which is form of soil washing used specifically with rad metals | Readily implementable but requires consent of proprietary vendor for implementation | High Capital<br>Moderate O & M |
| | | Segmented Gate System | Effective for removal of discrete radioactive particles. Effectiveness for contaminants distributed by weathering would be determined by treatability studies | Readily implementable Uses common sand-and-gravel handling equipment and common radiation monitors. Control software and design are proprietary | Low Capital<br>Moderate O & M |
| | Thermal | Vitrification | Very effective for containing radionuclides in glassy solid matrix which is resistant to leaching | Innovative technology which is difficult to implement based on its complexity | Very High Capital<br>Very High O & M |

Figure A-4 Evaluation of Process Options for Soils (Cont )

## APPENDIX B
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## B 1 0 INTRODUCTION

Appendix B presents the results of a subsurface solute transport model of the OU 1 site The purpose of the model is to provide a basis for residual risk calculations and design calculations for the feasibility study In this section the following topics are discussed the hydrogeological conceptual model of the site the framework of the corresponding numerical model the results and predictions of the model, and a qualitative discussion of model uncertainty **Tables and Figures are included in the back of this appendix, after references**

## B.2 0 HYDROGEOLOGICAL CONCEPTUAL MODEL

The conceptual model of OU 1 is a description of the primary processes that control the movement of solutes in the subsurface Such processes include groundwater flow rates and directions, solute release rates and timing recharge and discharge rates dispersion degradation rates and adsorption

The groundwater flow system beneath the hillside at OU 1 is described in detail in the Phase III RFI/RI (DOE 1994) The description here is limited to features incorporated into the flow and transport model of the site, and is further limited to the area of IHSS 119 1 IHSS 119 1 is where most of the observed contamination at the site is located

Groundwater flow beneath the hillside occurs in shallow colluvial, alluvial and bedrock units Most of the flow is concentrated in the colluvium and alluvium (DOE 1994) Groundwater flow tends to be focussed in areas where colluvium is thickest, these areas generally correspond to surface-water drainage features Such correspondence is likely due to deeper weathering of bedrock beneath surface channels One such surface channel feature extends upslope into IHSS 119 1 with a corresponding thicker section of colluvium It is along this subsurface feature that most of the groundwater flow in the vicinity of IHSS 119 1 occurs (Figures 3-23 and 3 24 of the Phase III RFI/RI) Therefore groundwater flow is generally channelized along surface water features

Recharge and dıscharge probably vary durıng the year at the hıllsıde However over long perıods of tıme an average rate of recharge or dıscharge ıs applıcable Recharge to the hıllsıde flow system ıs assumed to occur as subsurface flow from the Rocky Flats alluvıum and from bedrock beneath the Rock Flats alluvıum No sıte specıfic measurements of recharge or dıscharge on the hıllsıde are avaılable Dıscharge at the surface along the hıllsıde ıs assumed to occur most of the tıme due to low precıpıtatıon rates runoff due to topography partıally saturated condıtıons (wıth correspondıng smaller relatıve water permeabılıtes) the small permeabılıty of the colluvıum and alluvıum (both of whıch are derıved from the claystone and sıltstone of the bedrock) and frozen ground durıng wınter months Dıscharge ıs also assumed to occur as flow ınto Woman Creek as observed by Fedors et al (1993a and 1993b) and as ındicated by hydrualıc gradıents dırected toward the creek

The prımary source of contamınants ıs located ın the subsurface beneath IHSS 119 1 Durıng the 1960s and 70s drums of solvents were stored ın IHSS 119 1 (DOE 1994) Releases from the drums have resulted ın a resıdual DNAPL phase ın the subsurface around Well 4387 The resıdual DNAPL phase has not been dırectly observed, but ıs ındıcated by hıgh concentratıons of chlorınated solvents lıke PCE ın groundwater The start of release to groundwater ıs not precısely known but ıs assumed to be 1970 The release mechanısm to groundwater ıs dıssolutıon of the resıdual (ımmobıle) DNAPL phase

The transport of contamınants ın groundwater ıs controlled prımarıly by groundwater flow dırectıons and rates Other processes that affect contamınant movement and mobılıty are dıspersıon degradatıon adsorptıon and volatılızatıon from groundwater to soıl gas Of these volatılızatıon ıs not ıncluded ın the model Dıspersıon ıs sımulated usıng dıspersıvıty, groundwater flow velocıty and molecular dıffusıon Degradatıon rates and sorptıon propertıes for solutes are dıscussed and reported the Phase III RFI/RI

## B 3 0 MODEL FRAMEWORK

The computer simulation code TARGET_2DU (Dames & Moore 1985) was used to simulate contaminant transport in the subsurface TARGET_2DU is a vertically oriented two-dimensional finite difference model that can simulate variably saturated conditions

Because the model is two dimensional it cannot simulate dispersion (spreading) transverse (perpendicular) to the model section Therefore dispersion in the plane of the model will be over predicted parallel and transverse to groundwater flow Consequently the model is more conservative (over predicts concentration and travel time) because it does not account for spreading of contaminants in transverse to the model plane

Another conservative aspect of the TARGET_2DU is that the mass adsorbed on soil is not decayed As constituents desorb the concentration on soil decreases but remains undecayed The result is a source in the model that decreases but at a rate slower than if decay were calculated for contaminants on soil Consequently the concentration of contaminants that desorb into water is higher than for the case in which decay on soil were calculated For contaminants with halflives that are short relative to the groundwater transport time the degree of over prediction is significant and is conservative

The model grid is 296 (horizontal) by 170 (vertical) cells (Figure B-1) with approximately 25 000 active cells The grid was designed to capture details of the bedrock/colluvium interface and topography, to accurately simulate the vadose zone and to minimize errors caused by numerical dispersion The location of the section of the model is shown in Figures B-2 and B-3, and corresponds to the trend of thicker colluvium which passes through IHSS 119 1

Two criteria are used to ensure minimal numerical dispersion the Peclet number and the Courant number The grid Peclet number is the ratio of grid spacing (length of a cell side) to dispersivity To minimize numerical dispersion the Peclet number should be less than or equal to one For this model dispersivity is much larger than cell lengths, so the Peclet number is much smaller than one The grid courant number is the ratio of time step interval to groundwater travel time across a cell Similar to the Peclet number the Courant number should be less than or equal to one Because gradients and hydraulic conductivities are small and because decay rates of the COCs are short the Courant number for this model is much smaller than one

The distribution of boundary conditions and material types are shown in Figure B-4 Properties associated with each of the material types and degradation rates and adsorption distribution coefficients for the contaminants of interest are listed in Table B-1 The list of contaminants is presented and discussed in Section 2 0

Each material type is assumed to be homogeneous where specified Therefore heterogeneity in the model is limited to three zones colluvium alluvium and bedrock Fractures in the colluvium resulting from mass movement of the colluvium down the hill are assumed to be healed so that fractures do not provide preferential flowpaths This is justified because the mass movement is generally relict (probably occurred during the Pleistocene) thus having had considerable time to heal and because the colluvial material being residuum bedrock is easily deformed so that voids cannot remain open over long periods of time

For the french drain a constant head/pressure cell was set at the bottom of the drain to simulate flow to the drain (elevation of the constant head is 5876 2 ft) The extraction well was simulated in the same manner but with an elevation of 5910 2 ft (see Figure B-5) These elevations are slightly above the interface between bedrock and colluvium material This was done based on the assumption that the French Drain and extraction well could not draw the water table all the way down to the interface (otherwise the saturated thickness approaches zero and flow decreases to zero) Simulations using the French Drain and extraction well are discussed in detail in following sections

The bottom of the model was select to be somewhat lower than the elevation of Woman Creek which is considered to be the ultimate sink for groundwater flowing down the hillside Because flow rates in the bedrock are much lower than those in the colluvium the model is less sensitive to the location of this boundary

The contaminant source was simulated using a constant concentration boundary condition based on the assumption that slow dissolution of residual DNAPL is the source of contamination in groundwater The source cell is located at the interface between bedrock and colluvium material in the model, in the area where high concentrations of contaminants in groundwater have been observed (Figure B 5)

## B 4 0 CALIBRATION

The model was calibrated to steady state average conditions as observed prior to the installation of the French Drain For calibration targets observed groundwater levels for wells 4387 0487 4787 and 5587 were compiled and averaged (Table B 2) For the purposes of computing target water levels dry (no measurable water) conditions were excluded from the average The results of the calibrated flow model are shown in Figure B 6 with point comparisons to average observed water levels (results of the flow and transport simulations are discussed in more detail in section B 5 0) To achieve calibration a net areal discharge of 2 96 in/yr from the water table was used as discussed in Section B 2 0

The flow mass balance provides a measure of how well the model is converged Discrepancies in the mass balance should be smaller than about 5% especially for groundwater flow otherwise errors in the flow domain may adversely affect subsequent transport simulations For the OU 1 model the percent discrepancy between simulated inflows and outflows for various times is (approximate values) 1 87% for steady-state flow 2 3% at the end of 23 years and 1 38% 0 18% and 5 31% at the end of the three predictive simulations respectively (see Section B 7 0) Convergence of the model was good exhibiting monotonic behavior

After calibrating the steady state flow transient transport simulations were done for each contaminant Transport simulations started with the steady state flow field continued for 20 years then incorporated the French Drain and extraction well as shown in Figure B 7 Each transport simulation was calibrated in a manner similar to that for the flow calibration Figures B 8 through B-17 show breakthrough curves for each of the contaminants with average upper bound and lower bound observed concentrations Data used to compute average minimum and maximum concentrations are listed in Table B 3 Calibrated source concentrations are 6 41 mg/ℓ for 1 1 DCE 9 63 mg/ℓ for PCE 0 64 mg/ℓ for $CCl_4$ 16 mg/ℓ for 1 1 1 TCA and 160 mg/ℓ for selenium

As with flow, the contaminant mass balance provides a measure of how well the model is converged Discrepancies in the mass balance should be smaller than about 10% For the OU 1 model and PCE, the percent discrepancy between the simulated mass in place, and mass influx and outflux for PCE at various times is (approximate values) 2 5% at the end of 23 years and -4 51% 5 76% and 10 09% at the end of the three predictive simulations respectively (see Section B 7 0) Convergence of the model is good exhibiting monotonic behavior

## B 5 0 RESULTS

From the calibrated steady state flow simulation (Figure B-6) groundwater rates and directions can be obtained Figure B-18 shows the effects of the French Drain and extraction well on groundwater flow The French Drain and extraction well both draw down the water table with drawdown cones that extend upgradient into IHSS 119 1 As expected the drawdown cones are asymmetrical due to the slope of the hill The simulated water levels correspond well with observed low water table conditions

Results of transport simulations for PCE are discussed in detail Results of simulations for other contaminants are not shown because the chemicals tend to behave similarly The PCE plume after 22 years (pre-French Drain) and at 23 and 24 years is shown in Figures B-19 B-20 and B-21 The plume moves down gradient slowly and also penetrates into the bedrock a small distance The majority of movement is in the colluvium due to higher groundwater flow rates

Some migration in the vadose zone is also simulated corresponding to dispersion in soil moisture

After 24 years the French Drain and extraction well have a slight effect on the plume (Figures B 20 and B-21) The extraction well pulls the plume back toward IHSS 119 1 and the French Drain captures the plume trapped between it and the extraction well

## B 6 0 UNCERTAINTY

This section is a qualitative discussion of uncertainties associated with the model In general uncertainties can be divided into two types The first type results from an incomplete knowledge of the system or processes A real system can often be too complex or lack the necessary information to be completely understood or modeled without making simplifying assumptions Parts of the system or processes may also be omitted because they are thought to be less important than others The second type of uncertainty relates to the values assigned to model input parameters used to describe the system or processes In reality input parameters are not single values but vary over a range of possible values

Table B-4 lists specific model assumptions or uncertainty factors (parameters) that could contribute to variations in model predictions The second column of the table gives the source of the uncertainty "Not simulated means a particular transport or transformation process was not considered in the modeling Measurement Error indicates that there could be some unknown, unmeasured variability or heterogeneity in the corresponding property Not measured indicates that the parameter has not been measured under site-specific conditions either in the field or in the laboratory In the third column, "Incorrect Flows" indicates that a different flow could result by a corresponding change in the parameter or assumption The fourth column lists the relative degree of uncertainty

## Table B-4
## Model Assumptions and Uncertainty Factors

| Model assumption or uncertainty factor | Cause of uncertainty or model error | Probable effect on model results | Relative degree of uncertainty |
|---|---|---|---|
| Two dimensional model | Three-dimensional transport not simulated | Incorrect spatial distribution of concentrations and incorrect flows | Low Model adequately matches general trends in the horizontal behavior of the observed plume Model is conservative due to over predication of lateral spreading |
| Porous media | Flow in fractures or other secondary porosity not simulated | Incorrect spatial distribution of concentrations and incorrect fluxes | Low Although slip subsurface failure planes have been mapped (DOE 1994) it is likely that such potential pathways have healed and are no longer permeable |
| Steady state flow | Transient flow is not simulated for calibration | Incorrect spatial distribution of concentrations and incorrect flows | Low Contaminant transport and fluctuations in flow become less important over long periods of time The model is conservative in simulating continually saturated conditions where seasonal wetting and drying is known to occur |
| Material properties are homogeneous within a model layer | Heterogeneity within model layers | Incorrect spatial distribution of contaminants incorrect flows | Low The primary hydrogeologic layers that effect transport are well characterized |
| Volatilization | Not simulated | Incorrect spatial distribution of contaminants | Low Model is conservative with regard to this process |
| Timing of release | Not well known | Incorrect spatial distribution of contaminants | Low Model is generally conservative |
| Nature of release | Processes other than dissolution are not modeled | Incorrect spatial distribution of contaminants | Low Model is generally conservative |
| Sorption | Linear sorption | Incorrect spatial distribution of contaminants | Low Organic carbon content of subsurface and surface materials is low |
| Natural recharge/discharge rates | Not measured | Incorrect spatial distribution of contaminants incorrect flows | Moderate Model is sensitive to this parameter |

## Table B-4
## (Continued)

| Model assumption or uncertainty factor | Cause of uncertainty or model error | Probable effect on model results | Relative degree of uncertainty |
|---|---|---|---|
| Decay and transformation | Multicomponent transport not simulated no site-specific data | Incorrect spatial distribution of contaminants | Low Model is conservative |
| Porosity | Measurement error | Incorrect spatial distribution of contaminants | Low Measurement error relatively small |
| Diffusion coefficient | Not measured | Incorrect spatial distribution of contaminants | Low Error is small and model is insensitive to this parameter |
| Dispersivity | Not measured | Incorrect spatial distribution of contaminants | Moderate Parameter is based on scale of site this is a standard assumption |
| Size of source | Not measured | Incorrect spatial distribution of contaminants | Low Model has been shown to be insensitive to source size (Fedors et al 1993) |

The combination of parameters used in the model is not considered to be unique Other combinations of the parameters may yield a similar result However the parameter values used generally lie within observed and accepted ranges and therefore the model is considered representative of site conditions However the model is conservative in that it does not account for volatilization of PCE DCE TCA and $CCl_4$ and it generally over predicts concentrations at Well 0487 For these reasons the model is considered to be highly conservative

## B 7 0 PREDICTIONS

For predictions in which the source is not remediated the source is assumed to be large enough to provide an infinite supply of groundwater contamination Therefore in such simulations the source concentration is held constant throughout the simulations For predicative simulations in which the source is remediated, the concentrations in a 200 foot long area of colluvium around IHSS 119 1 are set to the appropriate water quality standard

### B 7 1 No Action Alternatives

Under these alternatives (0 1) French Drain and extraction well are removed but the source is not remediated Transport simulations beginning from 1994 and continuing through 2024 were done for each of the contaminants of interest Figure B 22 shows the predicted PCE plume in 1998 Under this scenario, the plume continues to grow with time because the source remains in place providing a constant source of dissolved PCE In addition desorption begins to provide an undecayed source which results in conservatively high predicted concentrations

Figures B-23 through B-32 show the variation of concentration with time at the French Drain and Woman Creek These curves are typically called breakthrough curves At the French Drain the installation of the drain and extraction well cause a dip in concentrations After the drain and well are removed concentrations begin to recover and increase due to a continuing source and to desorption At Woman Creek similar results are obtained however due to the longer travel distance and time the features of the breakthrough curves are more subdued Peak concentrations are simulated for PCE and DCE

B 7 2 Institutional Control Alternatives With the French Drain

Under these alternatives (2, 3) the french drain and extraction well remain in operation in the future No remediation of the source takes place under this scenario Transport simulations beginning from 1994 and continuing through 2024 were done for each of the contaminants of interest Figure B-33 shows the predicted PCE plume in 1998 Under this scenario the plume is drawn to and captured by the extraction well and french drain In addition desorption begins to provide an undecayed source which results in conservatively high predicted concentrations

Figures B-34 through B-43 show the variation of concentration with time at the french drain and Woman Creek At the french drain the installation of the drain and extraction well cause a dip in concentrations With the drain and well in place concentrations peak for shorter halflife COCs Desorption still provides a decreasing but undecayed source At Woman Creek similar results are obtained, however due to the longer travel distance and time, the features of the breakthrough curves are more subdued Peak concentrations are simulated for PCE and DCE

B 7 3 Remediation Alternatives

Under these alternatives (4, 5 6, 7) the french drain and extraction well are removed, and the source is remediated Transport simulations beginning from 1994 and continuing through 2024 were done for each of the contaminants of interest For these simulations where the source is remediated a 200 foot long strip of colluvium assumed to be cleaned up to the appropriate water quality standard (see Table 2 1) Figure B-44 shows the predicted PCE plume in 1998 Under this scenario the plume that remains in place after the source is removed continues to move down gradient with time In addition desorption begins to provide an undecayed source, which results in conservatively high predicted concentrations

Figures B-45 through B-54 show the variation of concentration with time at the source french drain and Woman Creek At the french drain, the installation of the drain and extraction well cause a dip in concentrations The breakthrough curves exhibit behavior that is a combination of the other sets of alternatives concentrations rise briefly after the drain and well are removed but rapidly decrease due to source remediation Desorption still provides a decreasing but undecayed source At Woman Creek similar results are obtained however due to the longer travel distance and time the features of the breakthrough curves are more subdued Peak concentrations are simulated for PCE and DCE

## B 8 0 SUMMARY

A groundwater flow and contaminant transport model has been developed and calibrated for OU 1 The model was used to simulate and predict contaminant movement from IHSS 119 1 to the french drain and Woman Creek

The model is considered to be conservative for the following reasons

- The model is two dimensional therefore dispersion (spreading) in lateral to the plane of the model is not simulated This causes over prediction of concentrations

- The model does not account for decay of contaminants adsorbed to soil If desorption occurs then concentrations are conservatively over predicted

- The model does not account for volatilization of organic contaminants It is likely that volatilization is an important process because of high volatilization rates for these chemicals (high Henry's constants) and because of the short distance from groundwater to landsurface

- The model predicts increasing concentrations at locations like Well 0487 and 4387 where observed concentrations fluctuate around a generally constant average This most likely due to the way in which desorption is simulated and to ignoring the effects of volatilization

The model is calibrated to average site conditions for flow and transport with adequate agreement between the model and observed conditions The model has good mass balance and exhibits monotonic convergence indicative of accurate calculations

Three scenarios were simulated, each representing a set of alternatives Predicted results for no action alternatives indicate that concentrations at the french drain and at Woman Creek will increase to peak concentrations hundreds of years in the future Predicted results for institutional-controls and remedial alternatives indicate that concentrations at the french drain and at Woman Creek will increase slightly then decrease with time Peak concentrations are also hundreds of years in the future

The results of the model are used in characterizing risk associated with each of the alternatives

## B 9 0 REFERENCES


Dames & Moore 1985 TARGET *Dames & Moore Mathematical Model of Ground Water Flow and Solute Transport*

DOE 1994 *Final Phase III RFI/RI Rocky Flats Plant 881 Hillside Area (Operable Unit 1)* U S Department of Energy Rocky Flats Plant Golden Colorado November 1993

Fedors et al 1993a *Numerical Modeling of Variably Saturated Flow and Transport 881 Hillside* Rocky Flats Plant Jefferson County, Colorado Groundwater Technical Report Number 20 Colorado State University

Fedors et al 1993b, *Characterization of Physical and Hydraulic Properties of Surficial Materials and Groundwater/Surface Water Interaction Study at Rocky Flats Plant* Golden Colorado Colorado Groundwater Technical Report Number 21 Colorado State University

**Table B-1a**
**Media Specific Hydraulic Parameters Used in all Contaminant Simulations**

| Hydraulic Parameter | Units | Bedrock | Colluvium | Alluvium |
|---|---|---|---|---|
| Horizontal hydraulic conductivity | ft/d | 0 06 | 0 45 | 6 |
| Vertical hydraulic conductivity | ft/d | 0 06 | 0 2 | 3 |
| Specific storativity | 1/ft | 0 0001 | 0 00015 | 0 00035 |
| Porosity | | 0 35 | 0 36 | 0 45 |
| Bulk density ratio | | 1 81 | 1 5 | 1 65 |
| Distribution coefficient | $ft^3$/lb | 0 0578 | 0 0578 | 0 0578 |
| Molecular dispersion | $ft^2$/d | 0 0001 | 0 0001 | 0 0001 |
| Longitudinal dispersivity | ft | 20 | 30 | 40 |
| Transverse dispersivity | ft | 2 | 10 | 10 |
| Coefficient for Sr (psi) | 1/ft | 0 24 | 0 0558 | 3 |
| Coefficient for Sr (psi) | | 1 09 | 1 22 | 2 5 |
| Coefficient for Sr (psi) | | -0 0826 | -0 18 | -0 6 |
| Residual moisture content | | 0 25 | 0 19 | 0 1 |
| Saturated moisture content | | 0 35 | 0 36 | 0 45 |
| Coefficient for Kr (psi) | 1/ft | 0 83 | 0 0148 | 3 48 |
| Coefficient for Kr (psi) | | 0 41 | 0 44 | 1 93 |
| Coefficient for Kr (psi) | | 3 | 10 | 3 |
| Minimum Kr (psi) | | 0 1 | 0 1 | 0 1 |

## Table B-1b
## Contaminant-Specific Modeling Parameters

| Contaminant | Distribution Coefficient ($ft^3/lb$) |
|---|---|
| 1 1-dichloroethene | 0 0104 |
| Tetrachloroethene | 0 0578 |
| Carbon tetrachloride | 0 0704 |
| 1 1 1 trichloroethane | 0 0243 |
| Selenium | 2 4 |

## Table B-2a
## Measured Water Levels at Well 4387

| Date | Measured Water Level (ft ) |
|---|---|
| 4/27/89 | 5917.2 |
| 5/18/89 | 5917.2 |
| 6/10/89 | 5917.3 |
| 6/29/89 | 5917.0 |
| 7/14/89 | 5916.8 |
| 8/18/89 | 5916.9 |
| 8/25/89 | 5915.2 |
| 9/12/89 | 5916.4 |
| 10/26/89 | 5916.8 |
| 1/16/90 | 5916.6 |
| 2/1/90 | 5916.6 |
| 4/13/90 | 5920.4 |
| 6/7/90 | 5920.2 |
| 7/12/90 | 5919.3 |
| 8/9/90 | 5918.9 |
| 9/11/90 | 5918.3 |
| 9/12/90 | 5915.7 |
| 10/1/90 | 5917.9 |
| 11/7/90 | 5917.7 |
| 11/13/90 | 5917.7 |
| 12/6/90 | 5917.4 |
| 1/3/91 | 5917.3 |
| 3/18/91 | 5917.0 |
| 4/1/91 | 5916.6 |
| 5/7/91 | 5917.2 |
| 5/13/91 | 5917.2 |
| 6/11/91 | 5917.5 |
| 7/5/91 | 5917.2 |
| 8/6/91 | 5916.8 |
| 8/14/91 | 5916.9 |
| 9/5/91 | 5916.6 |
| 10/3/91 | 5916.5 |
| 11/5/91 | 5916.3 |

## Table B-2a
## (Continued)

| Date | Measured Water Level (ft ) |
|---|---|
| 12/2/91 | 5916.4 |
| 12/10/91 | 5916.4 |
| 1/3/92 | 5916.3 |
| 2/13/92 | 5916.5 |
| 3/5/92 | 5916.2 |
| 4/1/92 | 5918.5 |
| 5/5/92 | 5917.4 |
| 6/1/92 | 5917.7 |
| 6/23/92 | 5917.1 |
| 7/2/92 | 5917.2 |
| 8/3/92 | 5917.2 |
| 8/6/92 | 5917.3 |
| 9/4/92 | 5917.4 |
| 10/1/92 | 5916.6 |
| 10/27/92 | 5917.1 |
| 11/2/92 | 5916.8 |
| 12/3/92 | 5917.1 |
| 1/20/93 | 5916.7 |
| 2/2/93 | 5916.8 |
| 3/26/93 | 5917.8 |
| 4/2/93 | 5917.1 |
| 5/13/93 | 5917.3 |
| 6/17/93 | 5917.0 |
| 6/28/93 | 5916.9 |
| 7/13/93 | 5916.2 |
| Maximum | 5920.4 |
| Minimum | 5915.2 |
| Average | 5917.2 |

## Table B-2b
## Measured Water Levels at Well 0487

| Date | Measured Water Level (ft ) |
|---|---|
| 4/27/89 | 5900.5 |
| 5/19/89 | 5901.0 |
| 6/9/89 | 5902.0 |
| 6/29/89 | 5901.7 |
| 7/14/89 | 5900.6 |
| 7/26/89 | 5900.3 |
| 8/18/89 | 5900.0 |
| 9/13/89 | 5899.7 |
| 10/16/89 | 5899.2 |
| 1/16/90 | 5899.2 |
| 1/31/90 | 5899.2 |
| 4/12/90 | 5905.7 |
| 6/7/90 | 5904.1 |
| 7/11/90 | 5902.1 |
| 8/8/90 | 5901.6 |
| 8/29/90 | 5900.8 |
| 9/12/90 | 5900.3 |
| 10/1/90 | 5899.9 |
| 10/29/90 | 5899.3 |
| 11/7/90 | 5899.3 |
| 12/6/90 | 5899.0 |
| 1/2/91 | 5898.7 |
| 3/18/91 | 5898.5 |
| 4/1/91 | 5898.5 |
| 5/7/91 | 5899.8 |
| 5/9/91 | 5899.8 |
| 6/5/91 | 5901.1 |
| 7/2/91 | 5900.5 |
| 8/6/91 | 5899.0 |
| 8/20/91 | 5898.8 |
| 9/3/91 | 5898.4 |
| 10/2/91 | 5897 5 |

## Table B-2b
## (Continued)

| Date | Measured Water Level (ft ) |
|---|---|
| 11/5/91 | 5896.6 |
| 1/3/92 | 5897 1 |
| 2/3/92 | 5897.2 |
| 2/11/92 | 5897.2 |
| 3/5/92 | 5897.6 |
| 4/6/92 | 5901.8 |
| 5/6/92 | 5901.8 |
| 5/11/92 | 5901.7 |
| 6/1/92 | 5901.6 |
| 7/1/92 | 5899.7 |
| 8/3/92 | 5900.5 |
| 8/12/92 | 5900.2 |
| 9/4/92 | 5900.7 |
| 10/1/92 | 5900.0 |
| 10/21/92 | 5899.5 |
| 11/3/92 | 5899.2 |
| 12/7/92 | 5898.6 |
| 1/20/93 | 5898.4 |
| 2/2/93 | 5898.3 |
| 3/10/93 | 5898.0 |
| 3/26/93 | 5898.2 |
| 4/8/93 | 5901.4 |
| 5/14/93 | 5901.6 |
| 5/20/93 | 5901.6 |
| 6/16/93 | 5901.1 |
| 7/13/93 | 5900.5 |
| Maximum | 5905 7 |
| Minimum | 5896 6 |
| Average | 5899 9 |

## Table B-2c
## Measured Water Levels at Well 4787

| Date | Measured Water Level (ft ) |
|---|---|
| 4/27/89 | |
| 5/19/89 | 5875.8 |
| 6/10/89 | 5877.3 |
| 6/29/89 | |
| 7/14/89 | |
| 7/26/89 | |
| 8/25/89 | |
| 9/13/89 | 5876.4 |
| 10/20/89 | |
| 1/16/90 | 5878.4 |
| 2/15/90 | 5875.9 |
| 4/12/90 | 5876.4 |
| 5/3/90 | 5876.5 |
| 7/11/90 | |
| 8/8/90 | 5875.1 |
| 9/11/90 | |
| 9/12/90 | |
| 10/1/90 | |
| 10/25/90 | |
| 11/7/90 | |
| 12/10/90 | |
| 1/2/91 | |
| 4/1/91 | |
| 5/7/91 | |
| 6/5/91 | 5877.2 |
| 7/2/91 | 5875.7 |
| 8/6/91 | |
| 8/19/91 | |
| 9/3/91 | |
| 10/2/91 | |
| 11/5/91 | 5875.0 |
| 12/10/91 | 5876.4 |

## Table B-2c
## (Continued)

| Date | Measured Water Level (ft ) |
|---|---|
| 1/10/92 | 5875.1 |
| 2/5/92 | |
| 2/11/92 | |
| 3/5/92 | 5875.0 |
| 4/6/92 | |
| 5/5/92 | 5879.2 |
| 6/10/92 | 5878.0 |
| 7/1/92 | 5877.2 |
| 8/5/92 | 5876.5 |
| 8/17/92 | 5876.2 |
| 9/4/92 | 5877.0 |
| 10/1/92 | 5876.2 |
| 10/21/92 | 5875.8 |
| 11/3/92 | 5875.2 |
| 12/7/92 | |
| 1/20/93 | 5875.2 |
| 2/2/93 | 5875.4 |
| 3/26/93 | 5875.4 |
| 4/2/93 | 5875.5 |
| 6/16/93 | 5876.2 |
| 7/2/93 | 5875.9 |
| Maximum | 5879 2 |
| Minimum | 5875 0 |
| Average | 5876 2 |

**Table B-2d**
**Measured Water Levels at Well 5587**

| Date | Measured Water Level (ft ) |
|---|---|
| 4/27/89 | 5850.7 |
| 5/19/89 | |
| 6/1/89 | 5850.7 |
| 6/29/89 | |
| 7/10/89 | 5850.7 |
| 7/28/89 | |
| 8/25/89 | |
| 9/14/89 | |
| 10/16/89 | |
| 1/16/90 | |
| 4/12/90 | 5853.5 |
| 5/4/90 | 5853.2 |
| 7/10/90 | 5852.2 |
| 7/19/90 | 5854.1 |
| 8/7/90 | 5851.2 |
| 9/12/90 | 5851.3 |
| 10/1/90 | 5851.3 |
| 10/29/90 | 5851.2 |
| 11/7/90 | 5850.7 |
| 12/6/90 | |
| 1/2/91 | 5850.7 |
| 3/18/91 | 5850.7 |
| 4/1/91 | |
| 5/7/91 | 5850.7 |
| 6/5/91 | 5850.7 |
| 7/2/91 | 5851.0 |
| 8/6/91 | 5851.1 |
| 8/19/91 | 5851.1 |
| 9/3/91 | |
| 10/2/91 | 5850.7 |
| 11/5/91 | 5850.6 |
| 11/14/91 | 5850.6 |

**Table B-2d**
**(Continued)**

| Date | Measured Water Level (ft ) |
|---|---|
| 12/2/91 | 5850.6 |
| 1/3/92 | |
| 2/3/92 | |
| 3/5/92 | 5850.6 |
| 4/1/92 | 5853.6 |
| 5/1/92 | 5852.9 |
| 5/7/92 | 5852.9 |
| 6/1/92 | 5851.7 |
| 7/1/92 | 5851.9 |
| 8/3/92 | 5851.8 |
| 8/17/92 | 5851.7 |
| 9/4/92 | 5851.0 |
| 10/1/92 | 5851.0 |
| 10/20/92 | 5851.1 |
| 11/3/92 | 5850.7 |
| 12/7/92 | 5850.7 |
| 1/19/93 | 5850.7 |
| 2/1/93 | 5850.7 |
| 3/4/93 | 5850.6 |
| 3/29/93 | 5850.7 |
| 4/7/93 | 5850.7 |
| 5/14/93 | 5850.9 |
| 5/18/93 | 5850.9 |
| 6/16/93 | 5850.9 |
| 7/6/93 | 5851.0 |
| Maximum | 5854 1 |
| Minimum | 5850 6 |
| Average | 5851 3 |

## Table B-3a
## Measured Concentrations of VOCs at Well 4387

| Date | Material Type | Tetra chloroethene (ug/l) | | | 1 1 Dichloroethene (ug/l) | | | 1 1 1 Trichloroethane (ug/l) | | Carbon Tetrachloride (ug/l) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Feb-01 1990 | Colluvium | 3600 | | | 4900 | | | 500 | U | 500 | U | |
| Jun-06-1990 | Colluvium | 61 | | | 38 | | | 110 | | 5 | U | |
| Jun-07 1990 | Colluvium | 82 | | | 53 | | | 140 | | 5 | U | |
| Sep-11 1990 | Colluvium | 1400 | E | | 2400 | | | 3200 | E | 400 | E | |
| Nov 14-1990 | Colluvium | 1500 | B | V | 1400 | V | | 3000 | | 120 | U | V |
| Mar-19 1991 | Colluvium | 2900 | | | 2900 | | | 5900 | B | 170 | U | |
| May 15 1991 | Colluvium | 6000 | D | JA | 8200 | D | V | 15000 | D | 5 | U | |
| Aug 15 1991 | Colluvium | 5700 | V | | 7200 | | V | 10000 | | 500 | U | V |
| Dec-12 1991 | Colluvium | 3400 | V | | 6000 | D | V | 14000 | D | 100 | U | V |
| Feb-18-1992 | Colluvium | 3200 | JA | | 4300 | D | V | 7400 | D | 5 | U | V |
| Jun-24-1992 | Colluvium | 1400 | V | | 1400 | | V | 2600 | | 40 | U | V |
| | Maximum | 6000 | | | 8200 | | | 15000 | | 500 | | |
| | Minimum | 61 | | | 38 | | | 110 | | 5 | | |
| | Average | 3000 | | | 4750 | | | 5750 | | 153 | | |

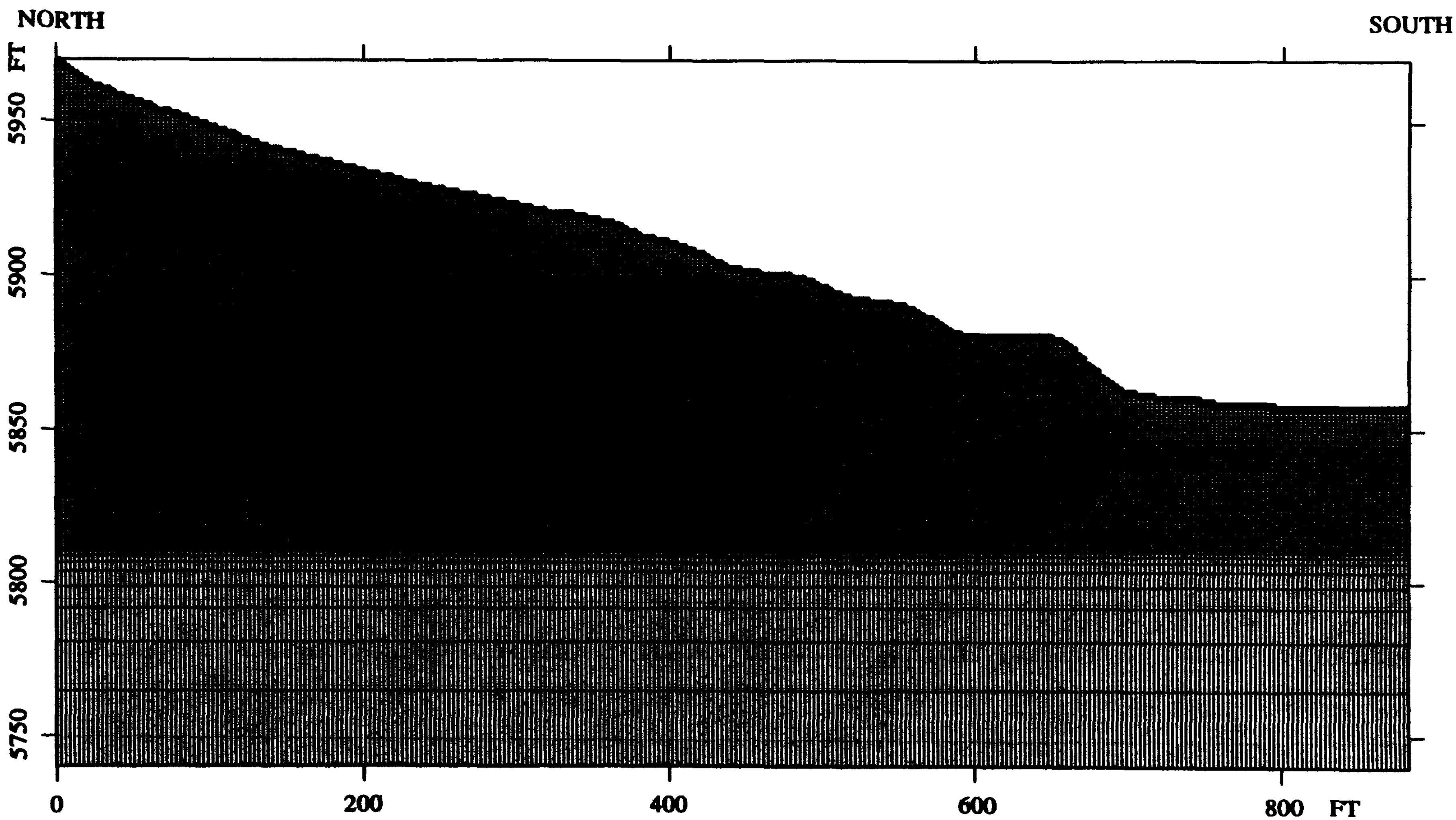
V = Valid
R = Rejected
B = Found in blank
E = Value > calibration range
JA = Estimated acceptable
U = Not detected at/above method detection limit
D = Dilution
J = Estimated value

## Table B-3b
## Measured Concentrations of VOCs at Well 0487

| Date | Material | Tetra chloroethene (ug/l) | 1 1 Dichloroethene (ug/l) | 1 1 1 Trichloroethane (ug/l) | Carbon Tetrachloride (ug/l) |
|---|---|---|---|---|---|
| Jan-31 1990 | Colluvium | 27 | 4 J | 2 J | 160 |
| Jun-07 1990 | Colluvium | 14 | 4 J | 7 | 55 |
| Aug 29 1990 | Colluvium | 21 | 5 | 8 | 95 |
| Oct 30-1990 | Colluvium | 5 | 5 U | 5 U V | 5 U V |
| Mar-19-1991 | Colluvium | 28 | 25 U | 25 U | 130 |
| May 10-1991 | Colluvium | 46 | 7 | 5 U V | 330 D V |
| Aug 21 1991 | Colluvium | 73 | 14 | 7 V | 280 D V |
| Feb-11 1992 | Colluvium | 55 | 9 2 | 5 | 240 |
| May 11 1992 | Colluvium | 10 | 20 U | 10 U | 120 |
| | Maximum | 73 | 25 | 25 | 330 |
| | Minimum | 5 | 4 | 2 | 5 |
| | Average | 41 3 | 8 7 | 5 7 | 205 |

V = Valid
R = Rejected
B = Found in blank
E = Value > calibration range
JA = Estimated, acceptable
U = Not detected at/above method detection limit
D = Dilution
J = Estimated value

K:\DESIGN\ \FLTS\HILL881\OU-1\GRAPHS\MESHPLOT.DWG

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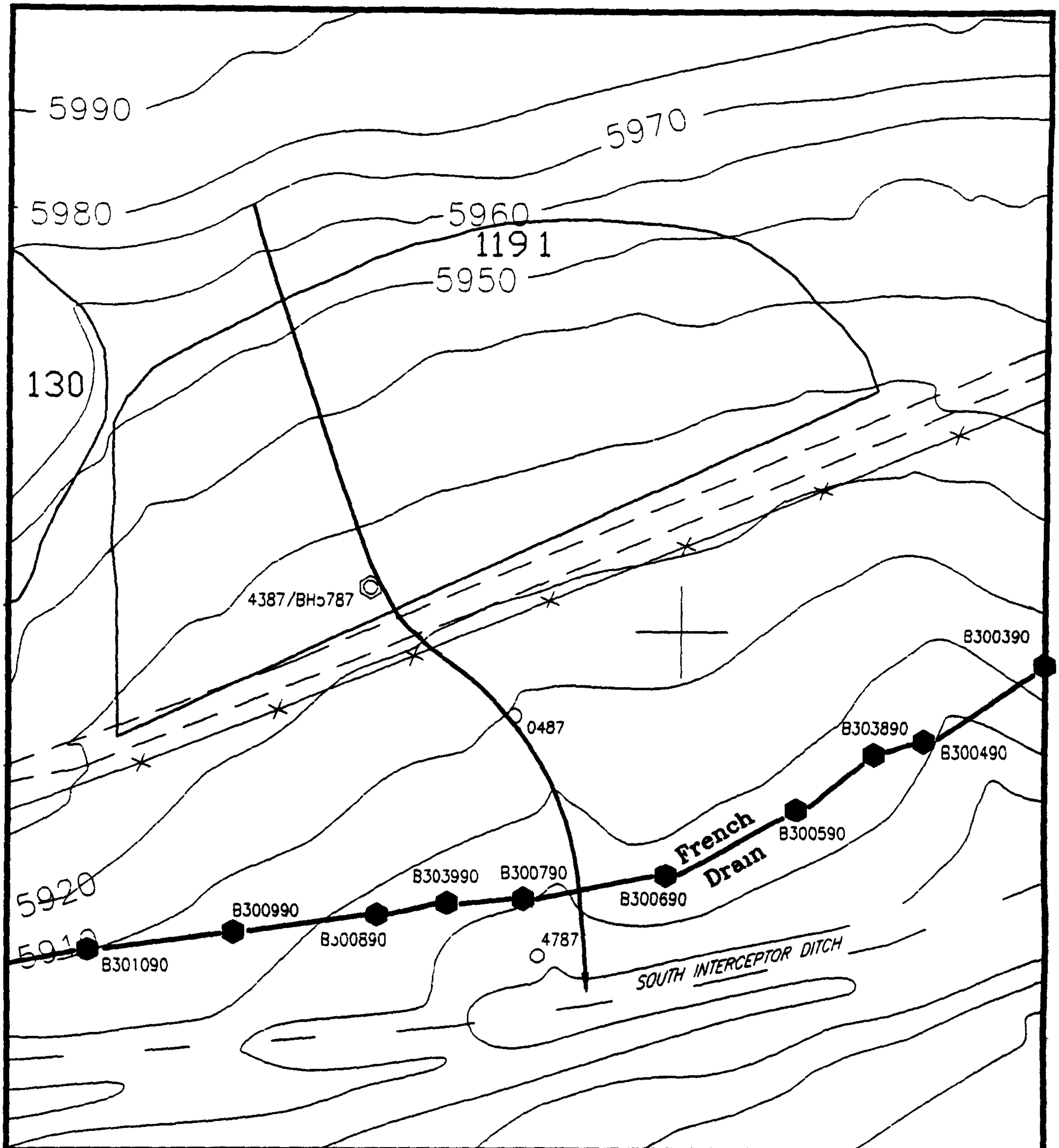
MODEL DISCRETIZATION

Figure B 1




EXPLANATION

| | |
|---|---|
| 104 | INDIVIDUAL HAZARDOUS SUBSTANCE |
| o B301889 | ALLUVIAL WELL |
| O BH1587 | BOREHOLE |
| ● B300390 | FRENCH DRAIN BOREHOLES |
| | CONTOUR INTERVAL = 10 FEET |

N

0 50 00
SCALE 100

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**Rocky Flats Plant, Golden Colorado**

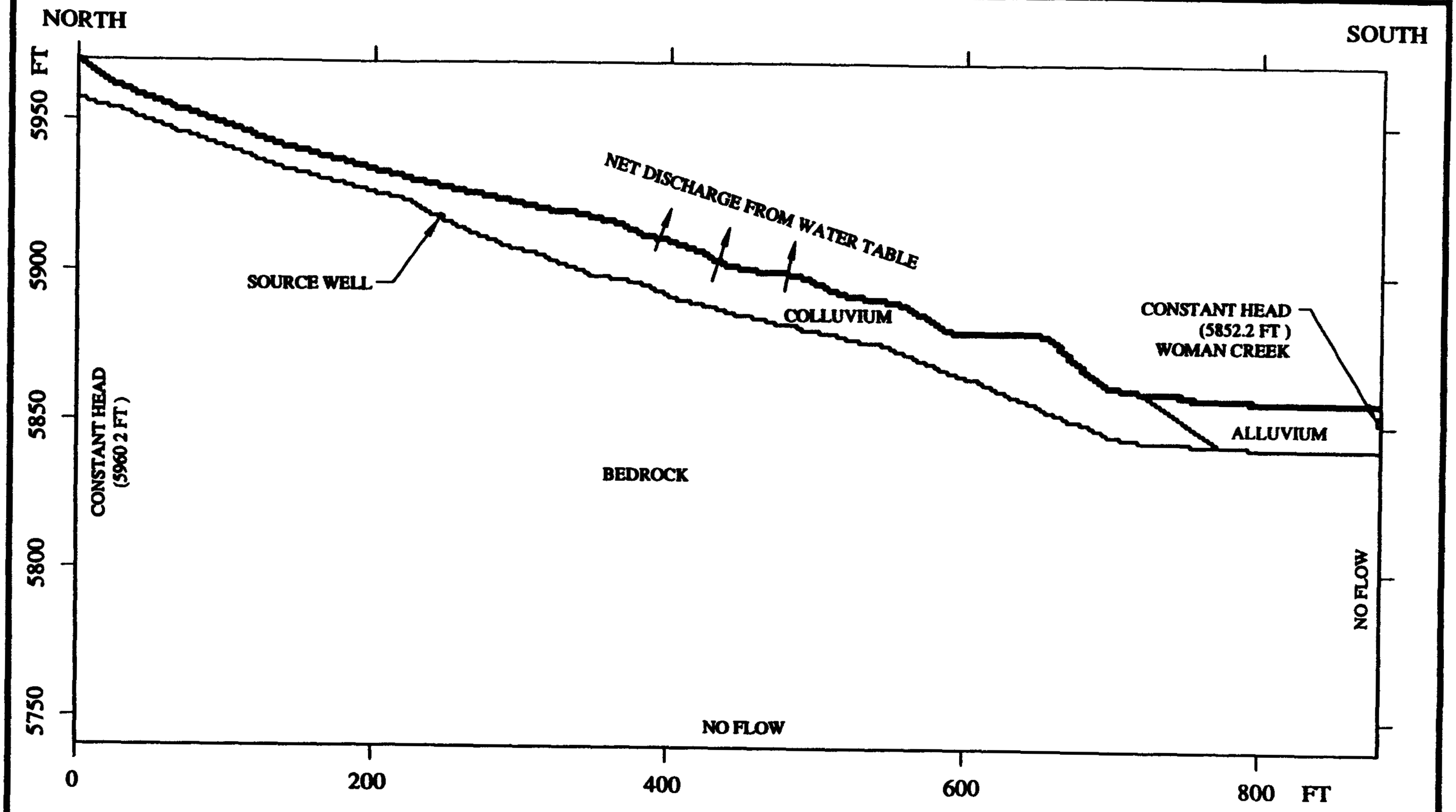
**881 HILLSIDE AREA**
**OPERABLE UNIT NO 1**
**PHASE III RFI/RI REPORT**

**Location of Model Section in IHSS 119 1**

**Figure B-3**

K:\DESIGN\RCKYFLTS\HILL881\OU 1\IHSS-119 DWG

K:\DESIG\ YFLTS\HILL881\OU-1\GRAPHS\MDLBND92 DWG

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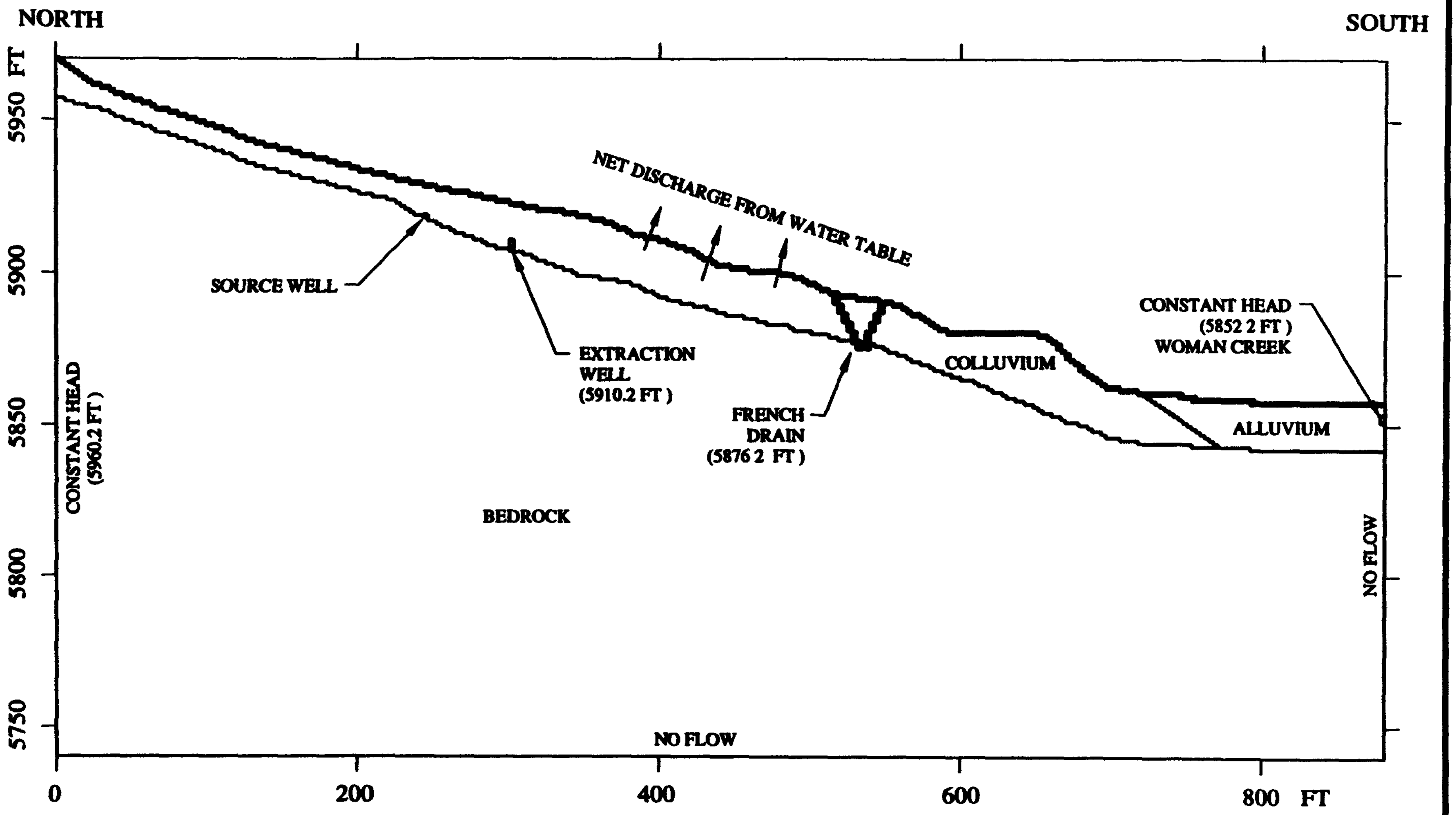
**MODEL BOUNDARY CONDITIONS**
**1992**

**Figure B-4**

K:\DESIGN YFLTS\HILL881\OU-1\GRAPHS\MDLBND94 DWG

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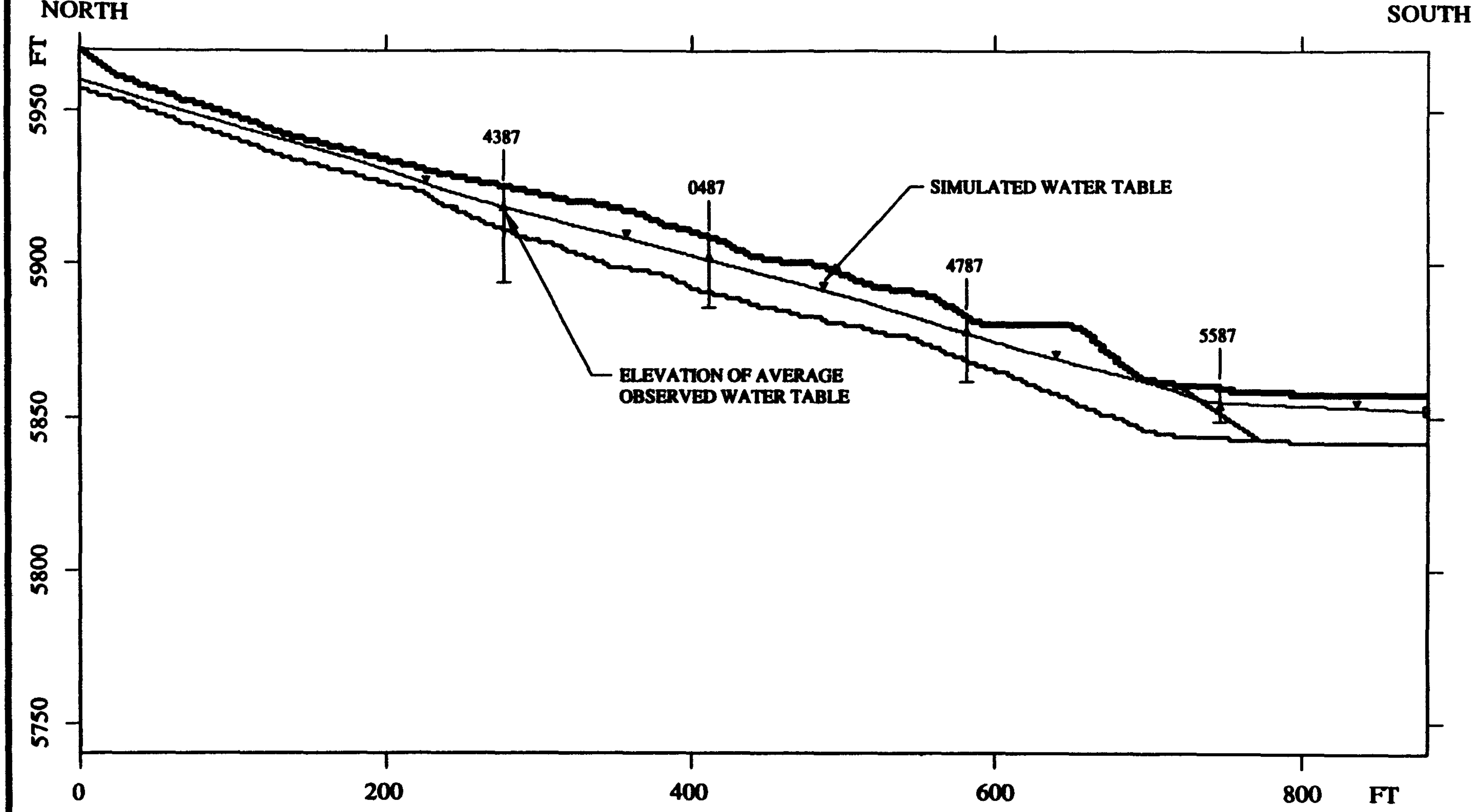
**MODEL BOUNDARY CONDITIONS 1994**

**Figure B 5**

K:\DESIGN\ FLTS\HILL881\OU-1\GRAPHS\WATERTBL.DWG

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Rocky Flats Environmental Technology Site
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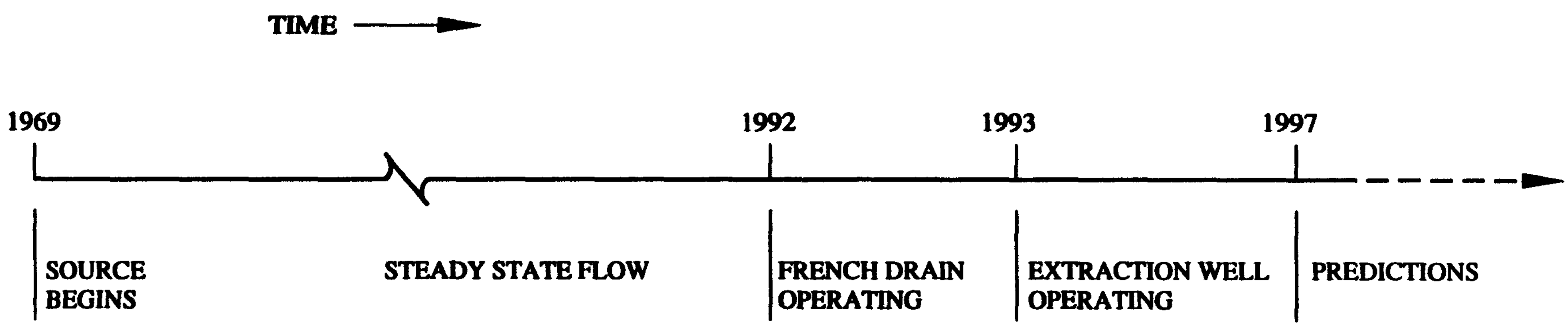
OPERABLE UNIT NO 1

**WATER TABLE**
**SIMULATED VS OBSERVED**

**Figure B-6**

K:\DESIGN YFLTS\HILL881\OU-1\GRAPHS\TIMELINE DWG

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OPERABLE UNIT NO 1

**MAJOR TIME EVENTS IN OU1 MODEL**

**Figure B 7**

# 1,1 DCE Calibration of well 4387
## Simulated Vs Observed

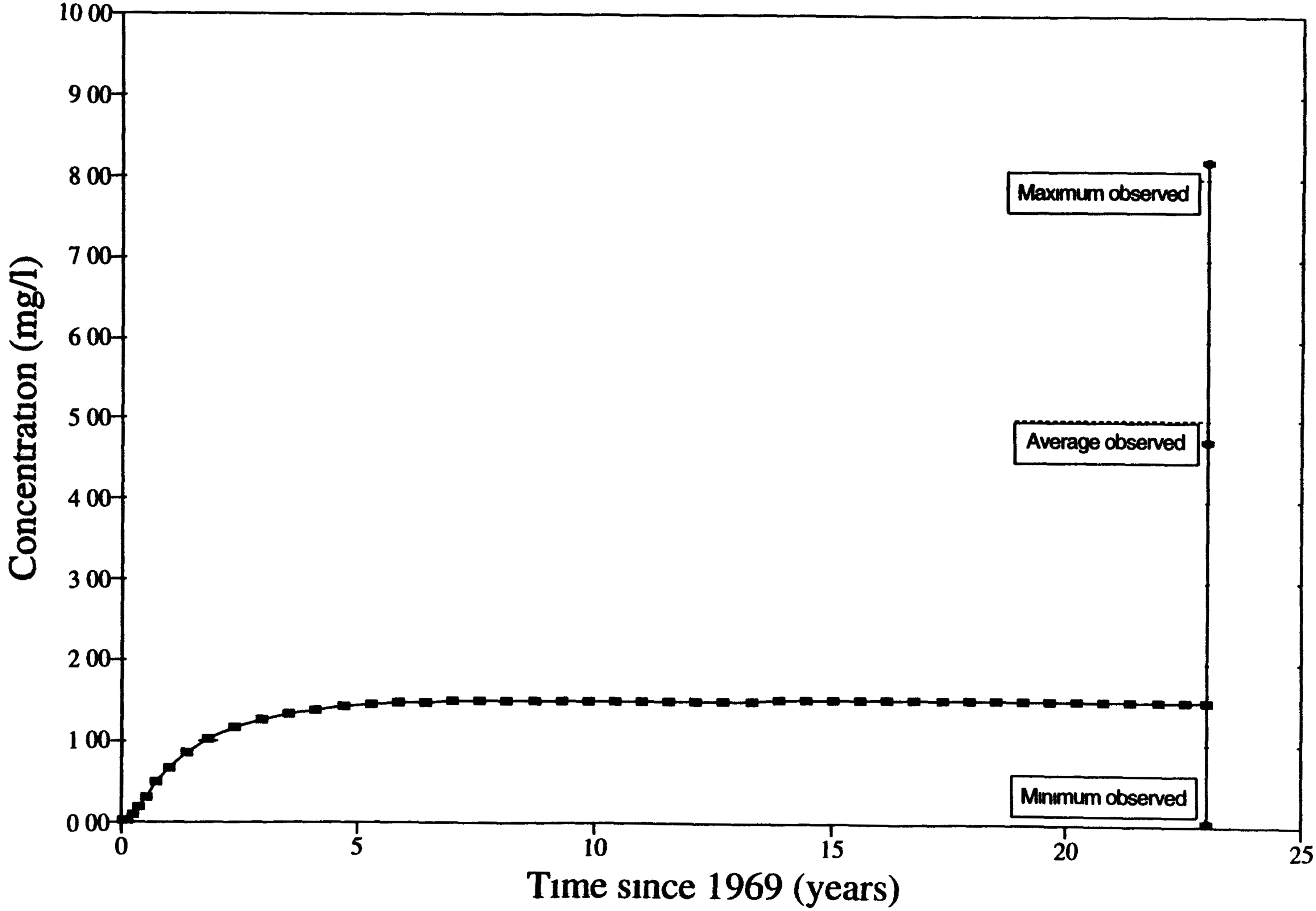



Figure B 8

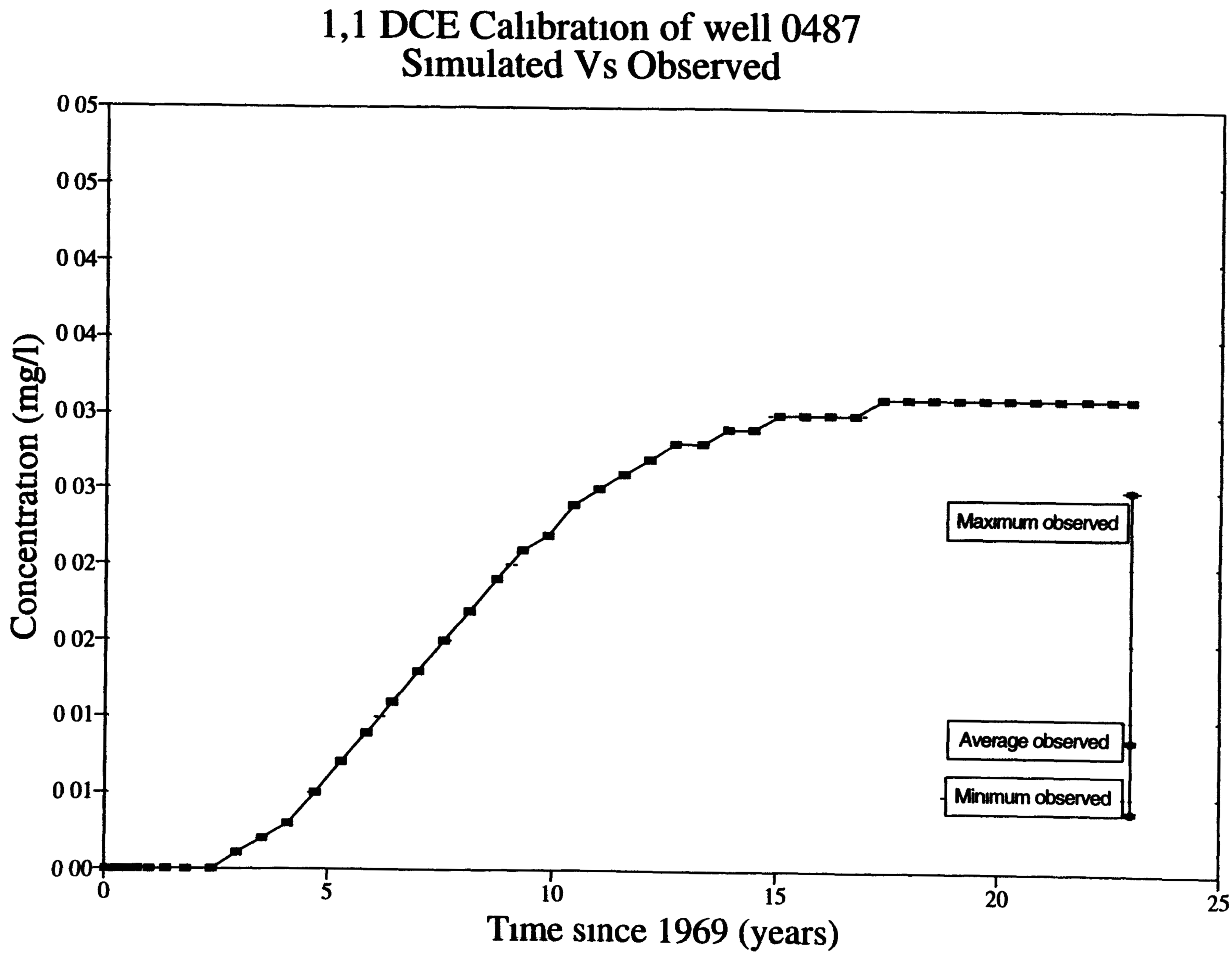
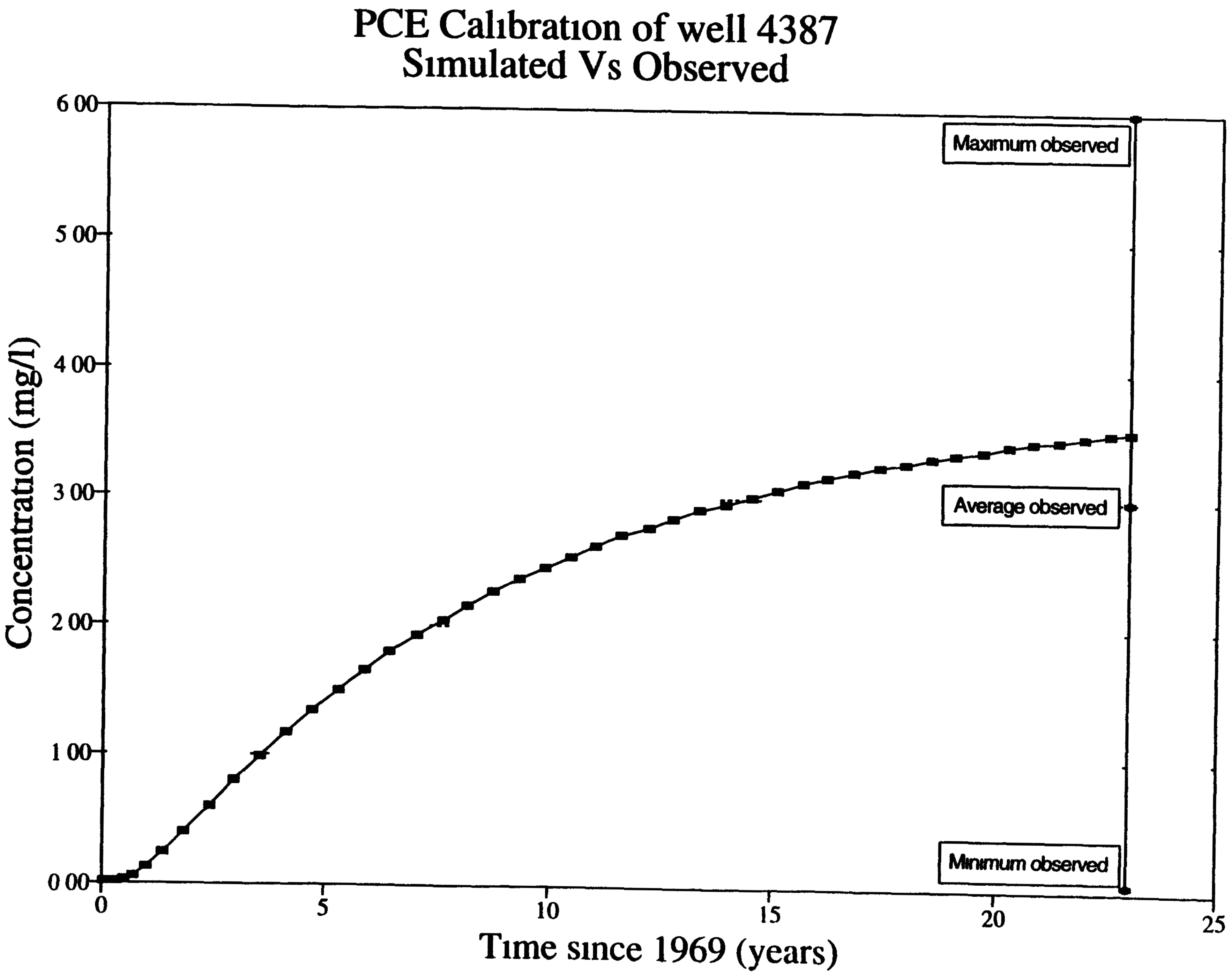

1,1 DCE Calibration of well 0487
Simulated Vs Observed
Concentration (mg/l)
0 05
0 05
0 04
0 04
0 03
0 03
0 02
0 02
0 01
0 01
0 00
0
5
10
15
20
25
Time since 1969 (years)
Maximum observed
Average observed
Minimum observed

Figure B-9



PCE Calibration of well 4387
Simulated Vs Observed
Concentration (mg/l)
6 00
5 00
4 00
3 00
2 00
1 00
0 00
0
5
10
15
20
25
Time since 1969 (years)
Maximum observed
Average observed
Minimum observed


Figure B 10

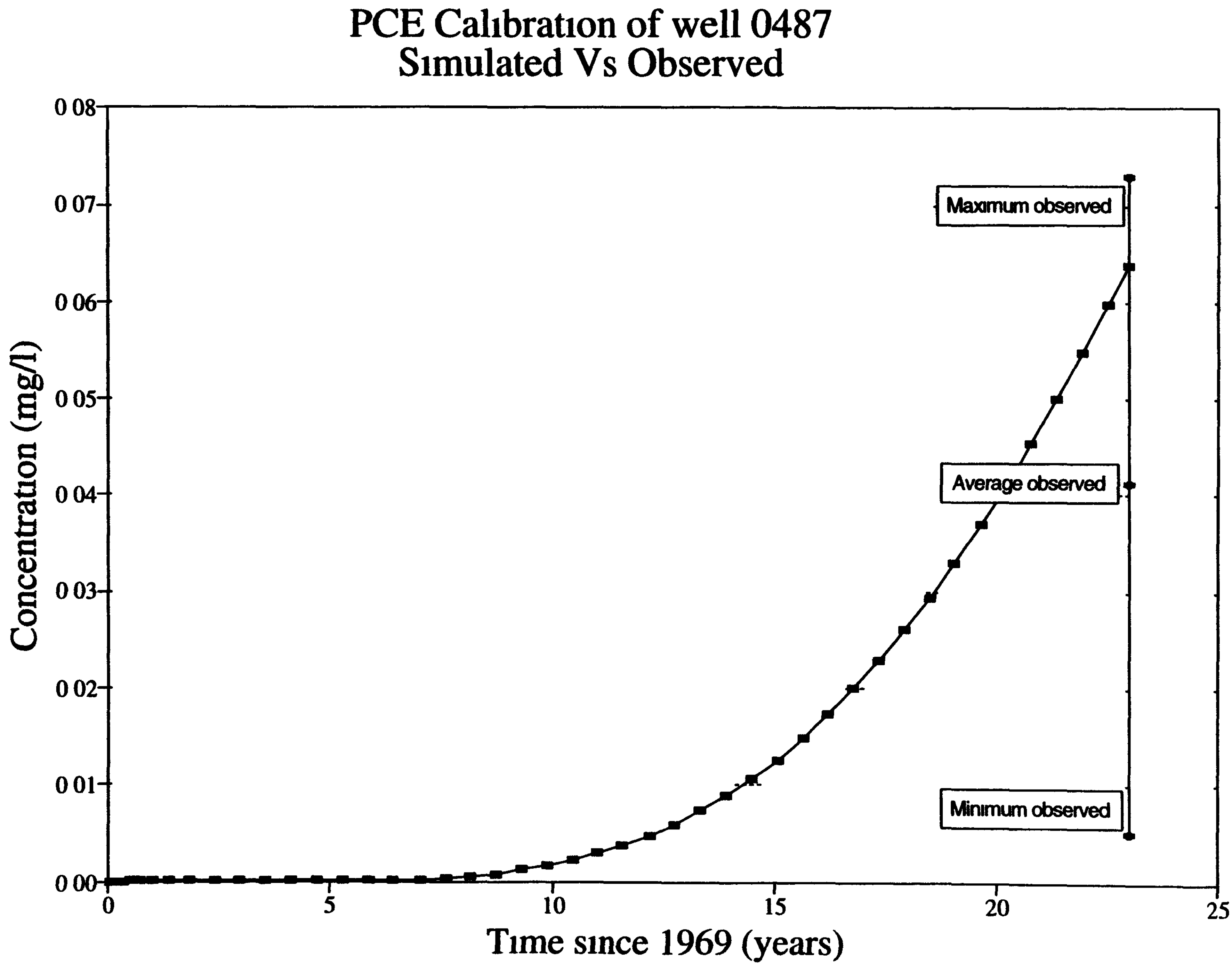

PCE Calibration of well 0487
Simulated Vs Observed
Concentration (mg/l)
0 08
0 07
0 06
0 05
0 04
0 03
0 02
0 01
0 00
0
5
10
15
20
25
Time since 1969 (years)
Maximum observed
Average observed
Minimum observed

Figure B-11

CCL Calibration of well 4387
Simulated Vs Observed

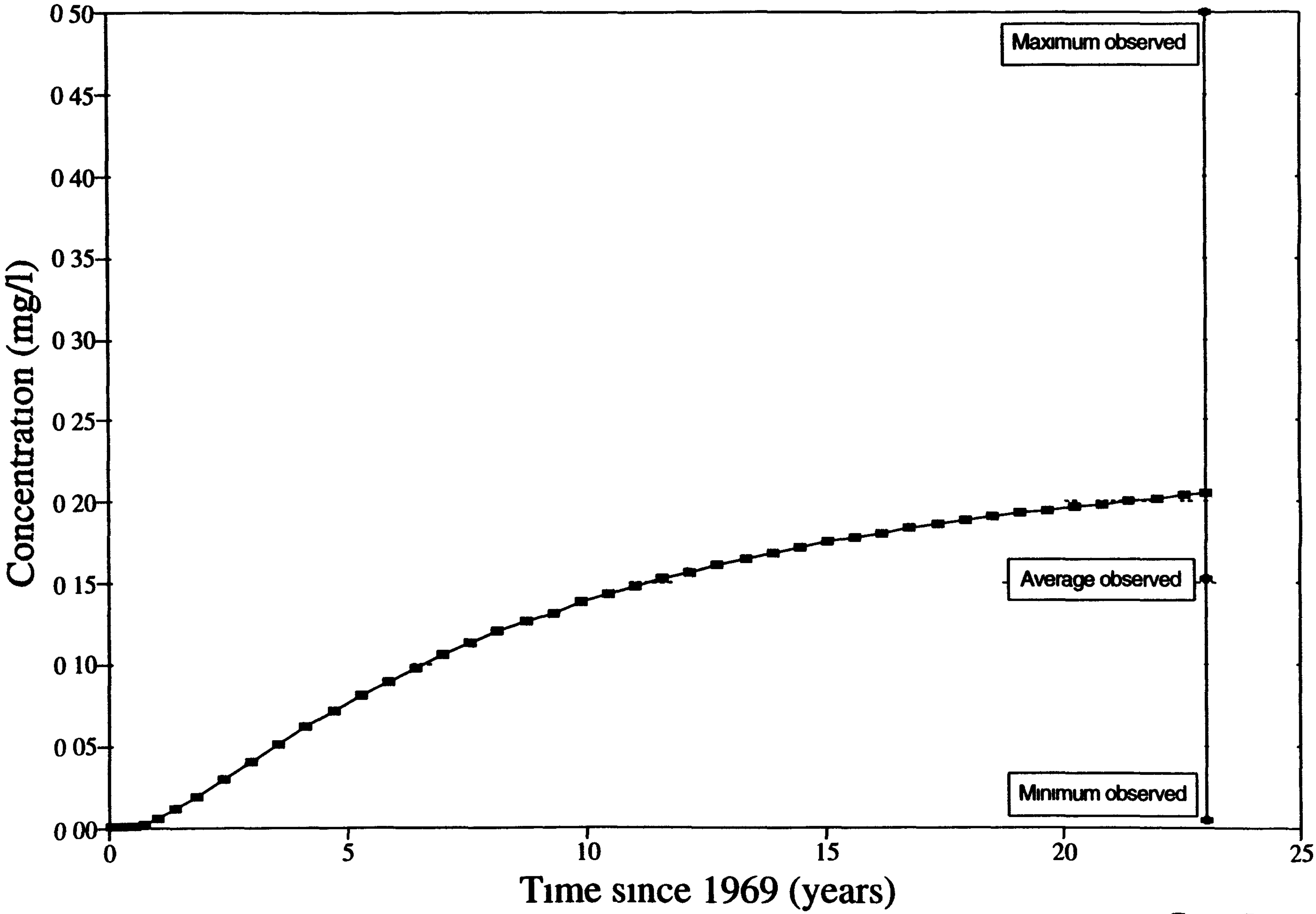



Figure B 12

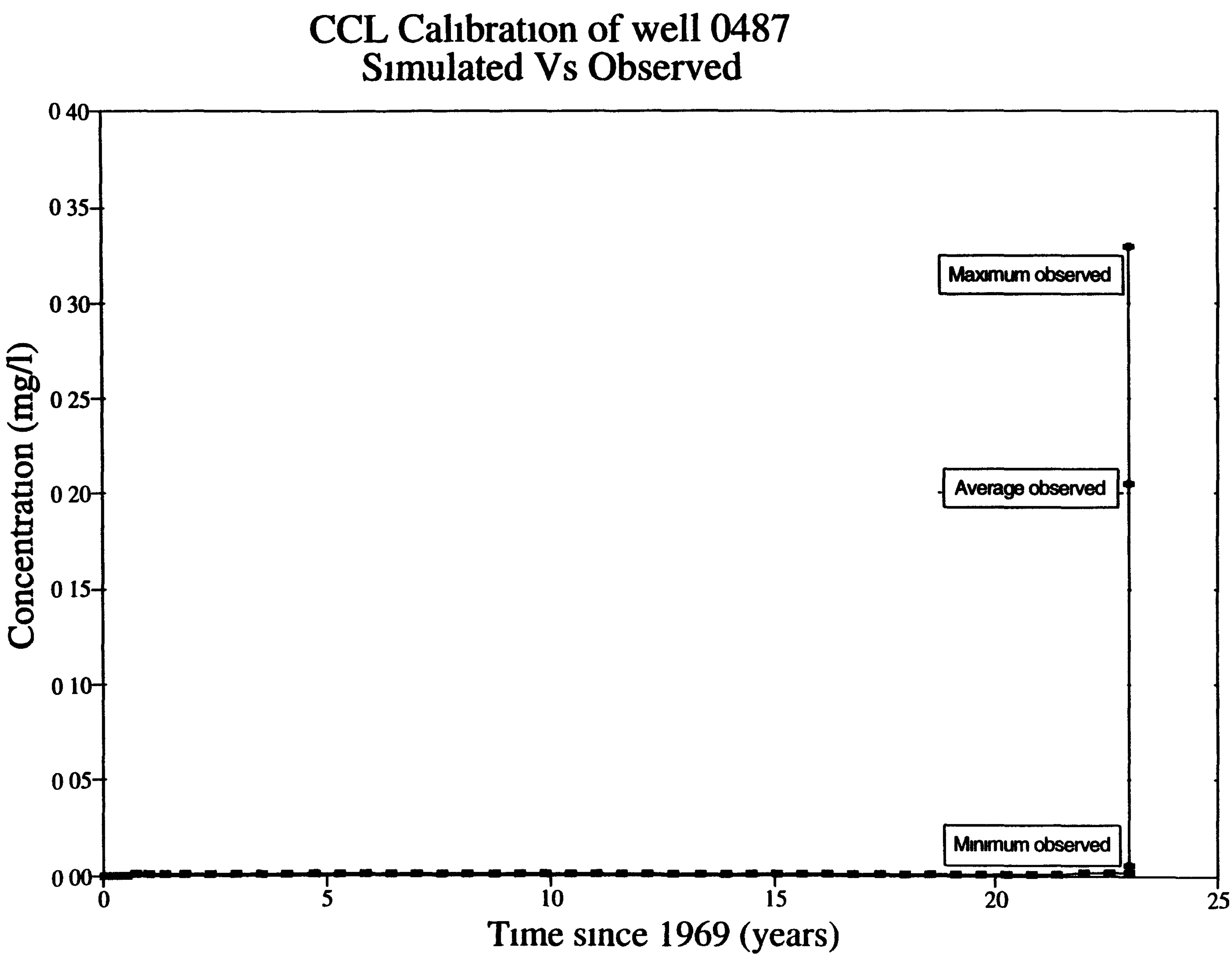

CCL Calibration of well 0487
Simulated Vs Observed
Concentration (mg/l)
0 40
0 35
0 30
0 25
0 20
0 15
0 10
0 05
0 00
0
5
10
15
20
25
Time since 1969 (years)
Maximum observed
Average observed
Minimum observed

Figure B 13

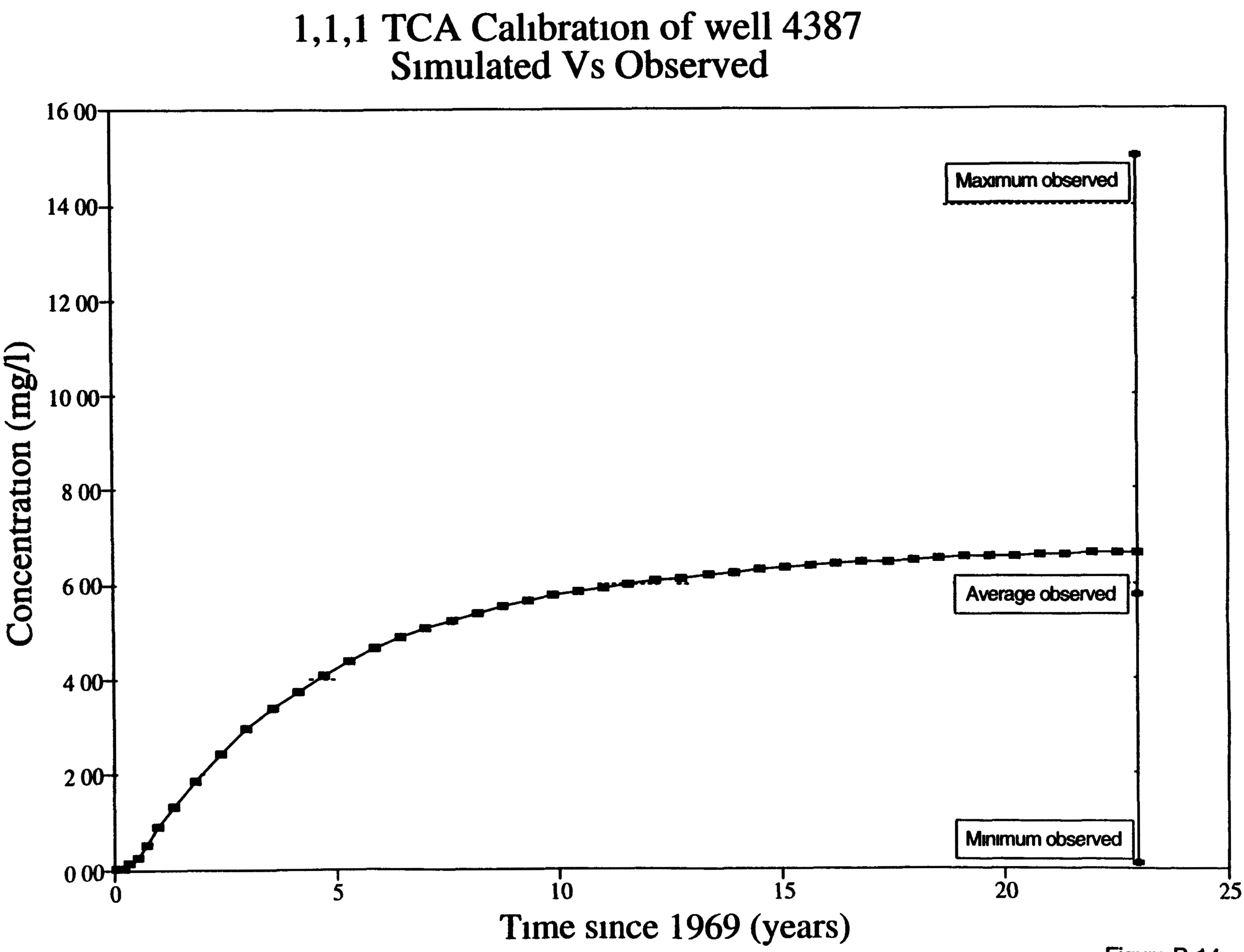

1,1,1 TCA Calibration of well 4387
Simulated Vs Observed
Concentration (mg/l)
16 00
14 00
12 00
10 00
8 00
6 00
4 00
2 00
0 00
0
5
10
15
20
25
Time since 1969 (years)
Maximum observed
Average observed
Minimum observed

Figure B 14

1,1,1 TCA Calibration of well 0487
Simulated Vs Observed

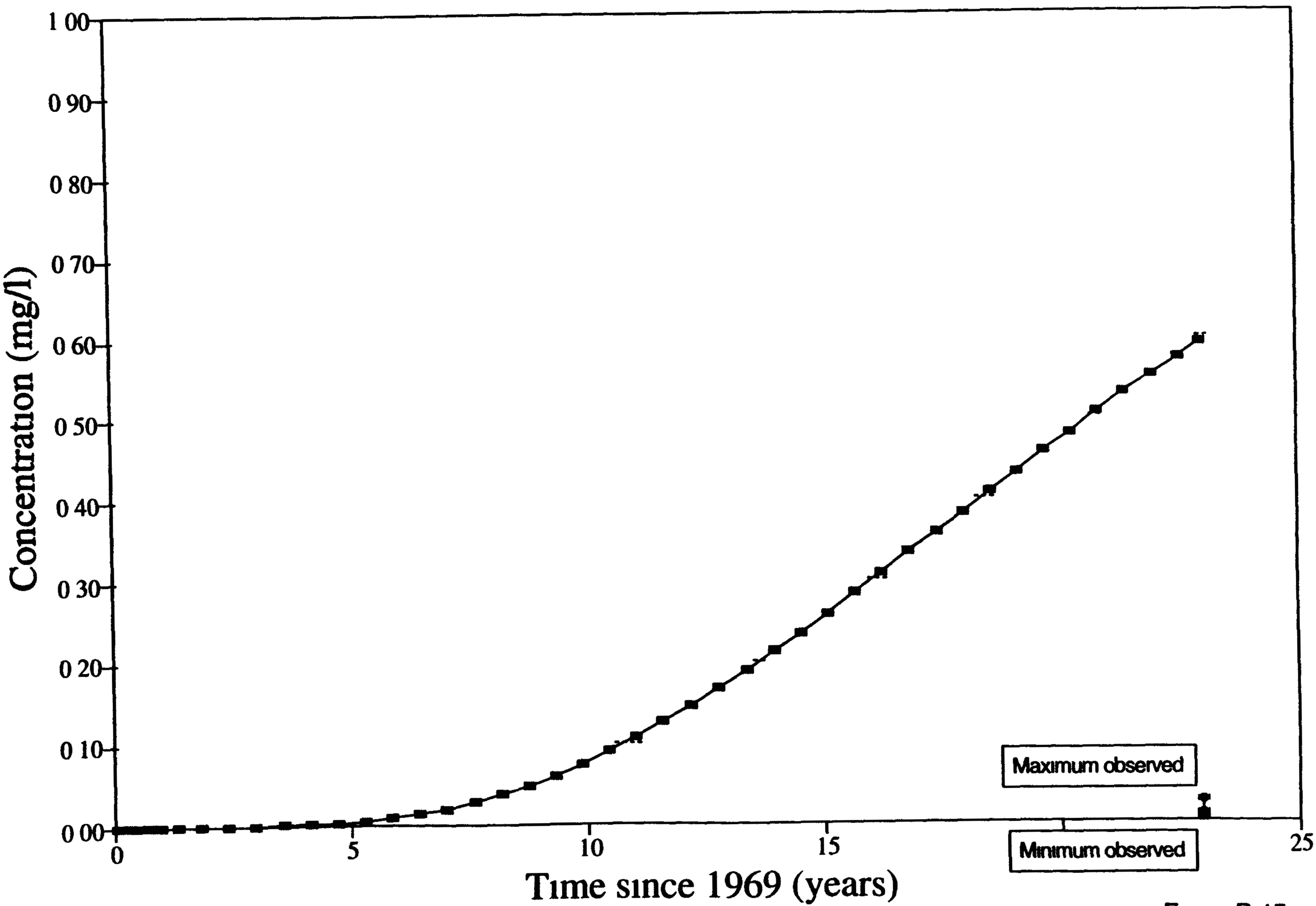



Figure B 15

## Selenium Calibration of well 4387
## Simulated Vs Observed

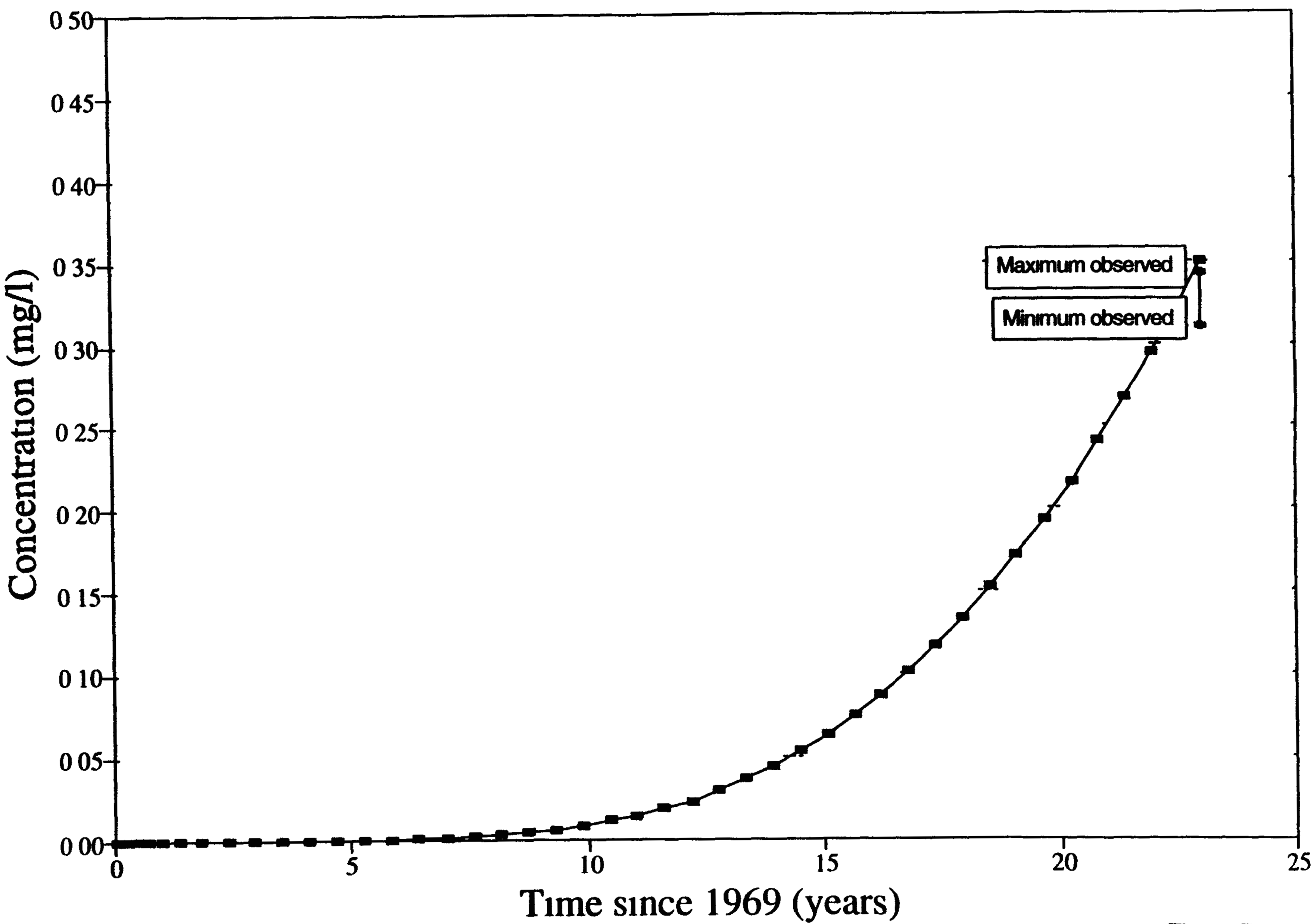



Figure B-16

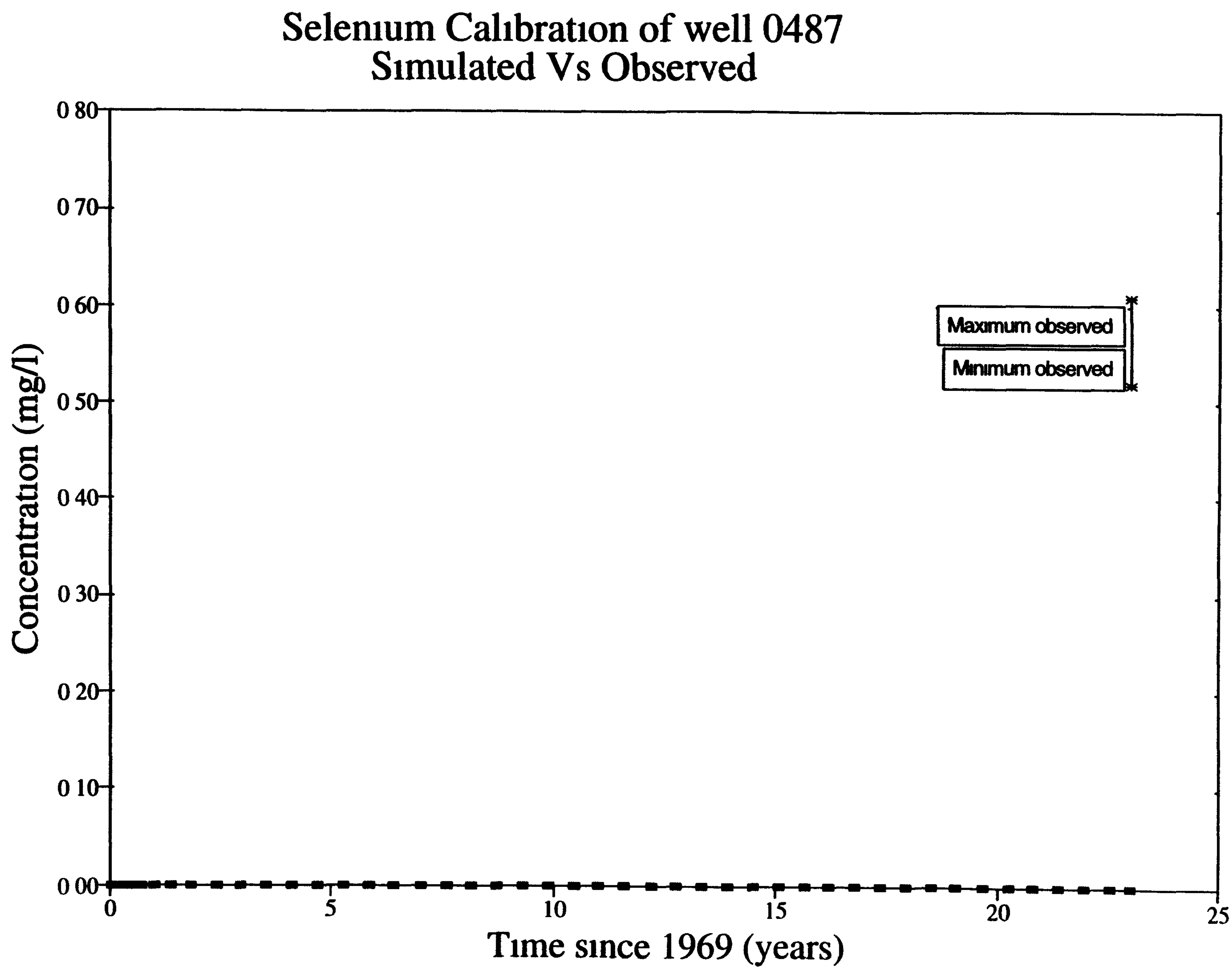
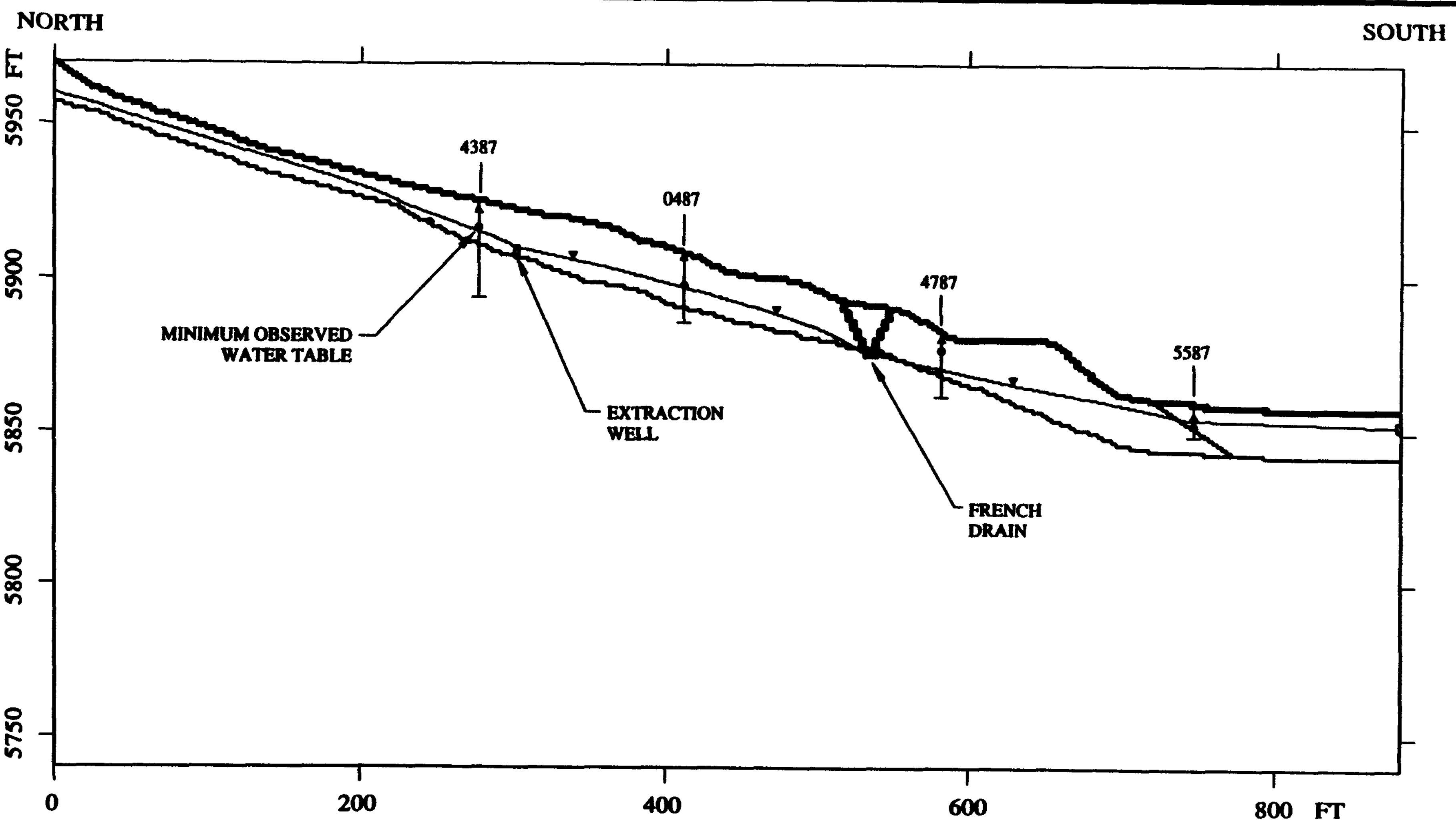

Selenium Calibration of well 0487
Simulated Vs Observed
Concentration (mg/l)
0 80
0 70
0 60
0 50
0 40
0 30
0 20
0 10
0 00
0
5
10
15
20
25
Time since 1969 (years)
Maximum observed
Minimum observed

Figure B 17

K:\DESIGN\ ... \FLTS\HILL881\OU-1\GRAPHS\WTRTBL94.DWG

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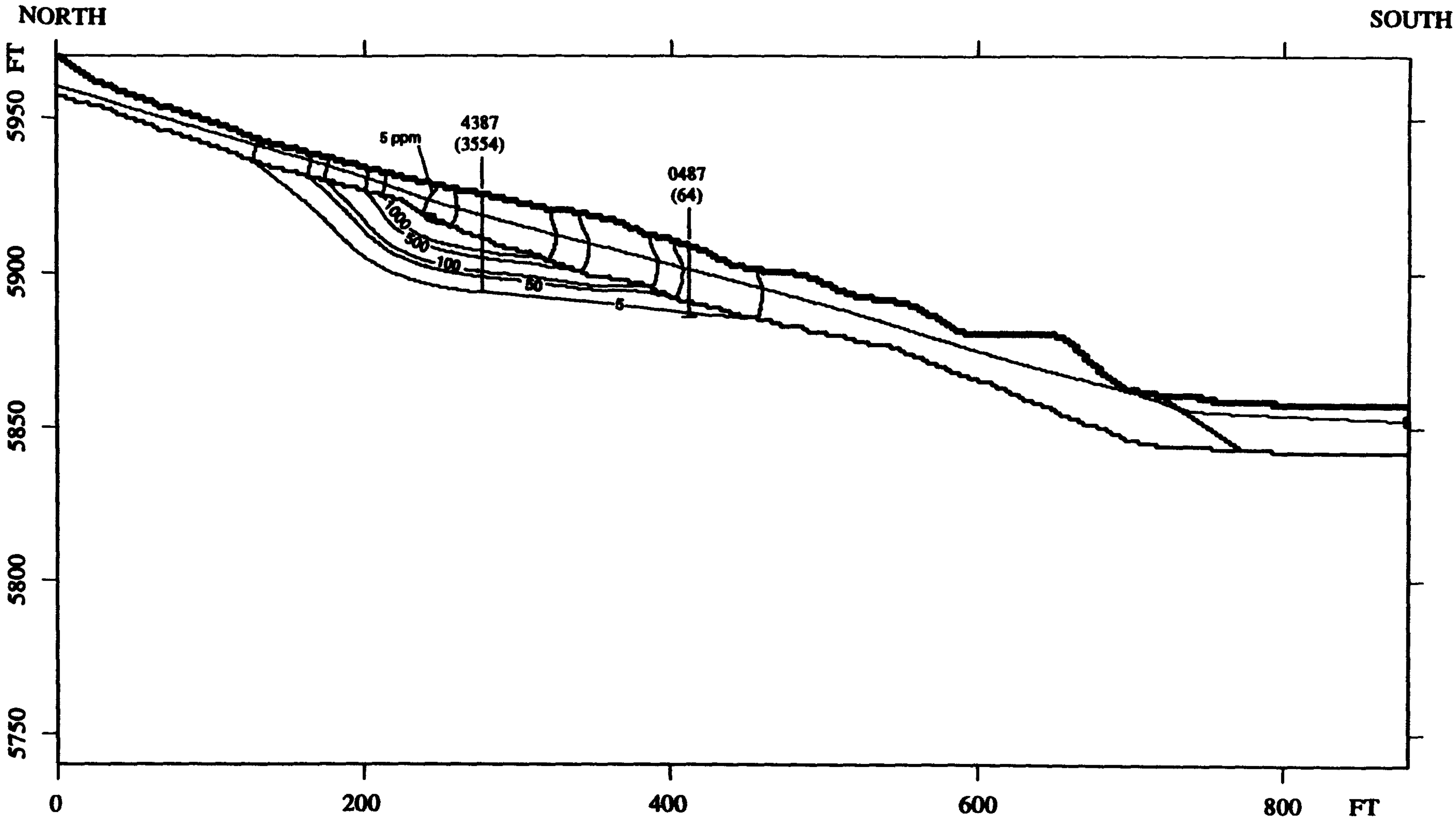
**WATER TABLE**
**SIMULATED VS OBSERVED**
**TIME = 9125 DAYS (1994)**

**Figure B-18**

K \DESIG    YFLTS\HILL881\OU 1\GRAPHS\PCE 1 DWG




## EXPLANATION

4387 WELL NUMBER

(3600) AVERAGE PCE CONCENTRATION IN ppb

NOTE Concentrations in ppb unless otherwise labeled.

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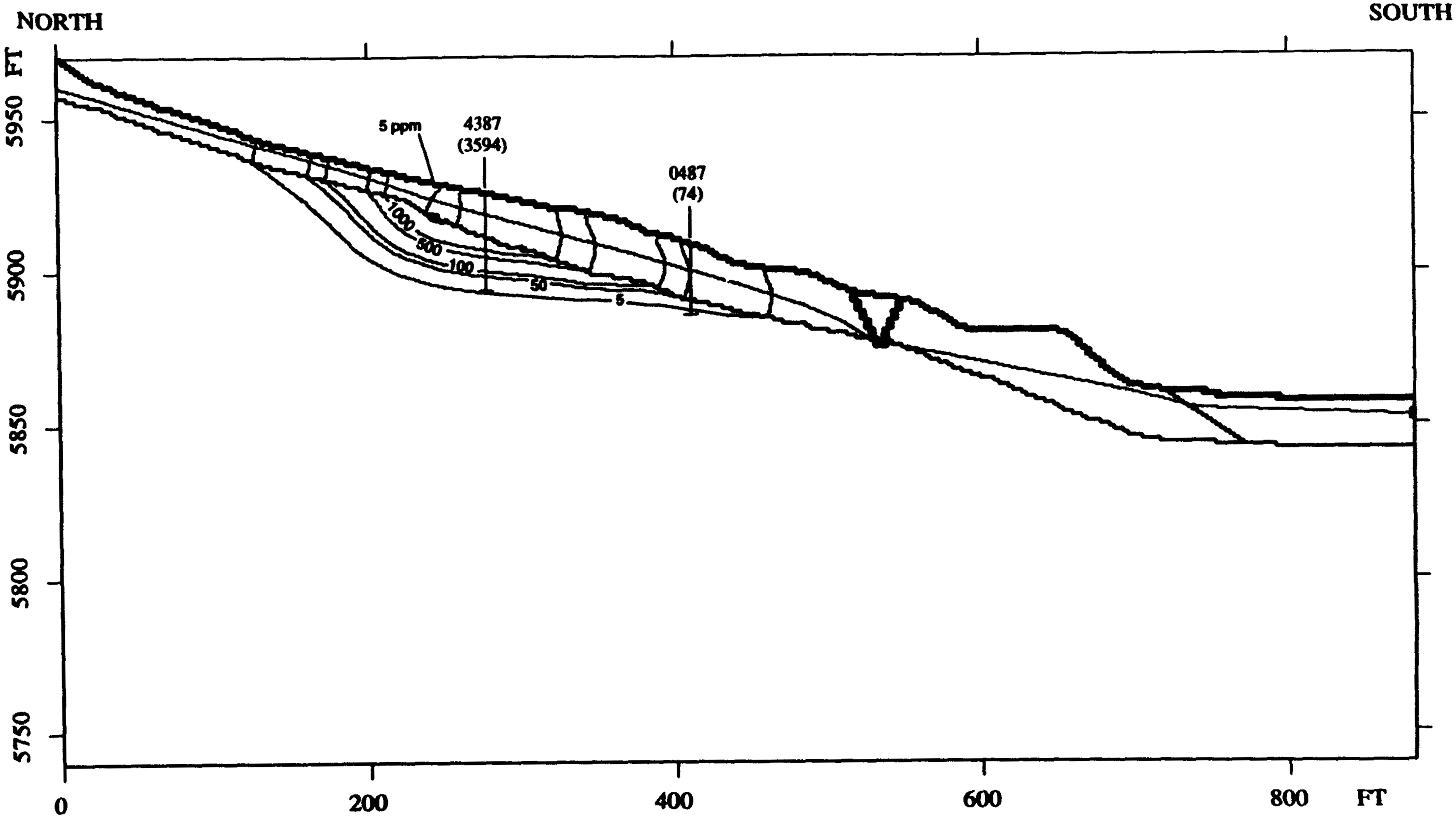
881 HILLSIDE AREA
OPERABLE UNIT NO 1

**CONCENTRATION CONTOURS OF PCE**
**TIME = 8395 DAYS (1992)**

**Figure B-19**

K:\DESIGN\R...YFLTS\HILL881\OU-1\GRAPHS\PCE-3 DWG




## EXPLANATION

4387 WELL NUMBER

(3600) AVERAGE PCE CONCENTRATION IN ppb

NOTE Concentrations in ppb unless otherwise labeled.

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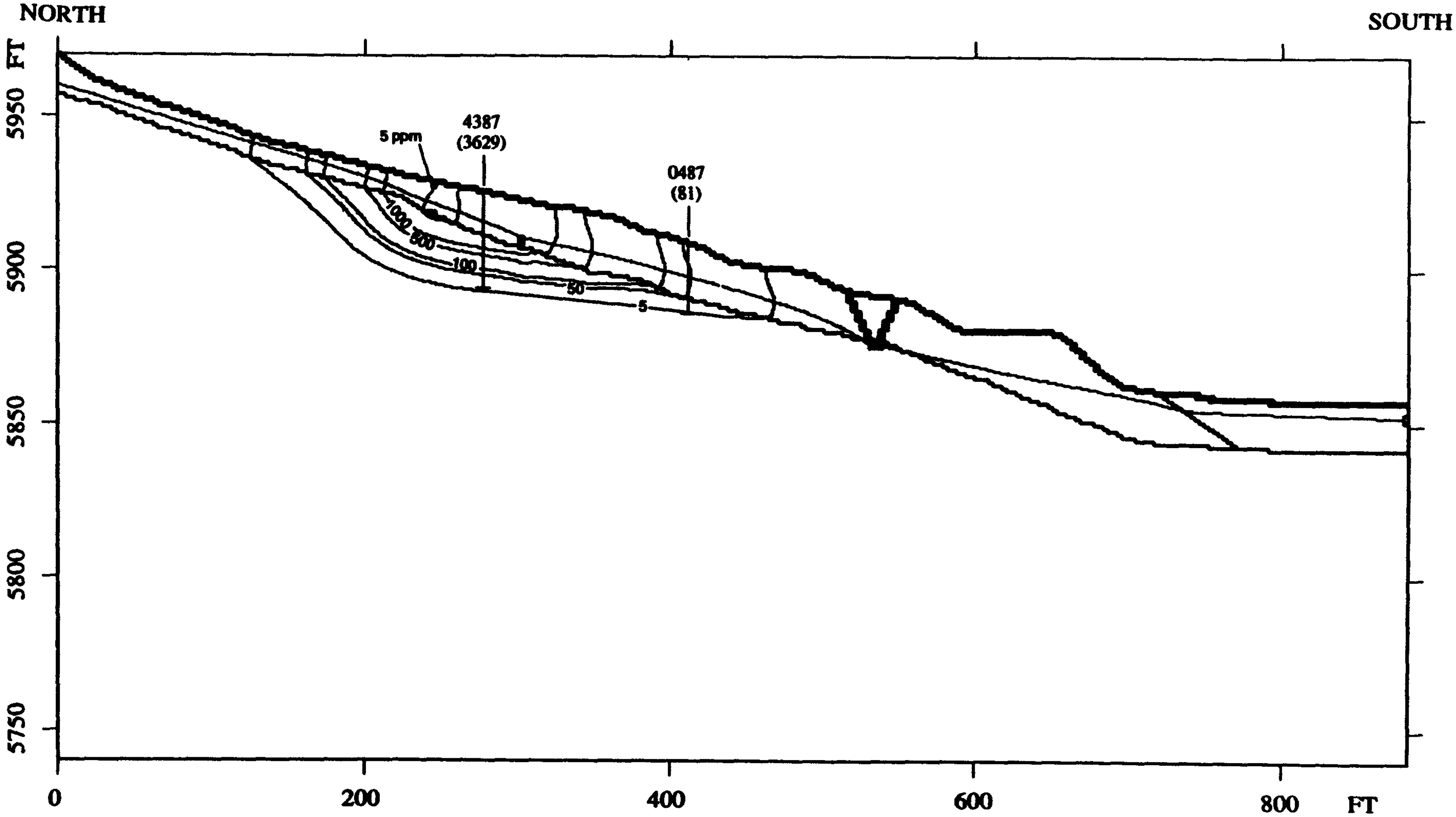
OPERABLE UNIT NO 1

**CONCENTRATION CONTOURS OF PCE**
**TIME = 8760 DAYS (1993)**

**Figure B-20**

K:\DESIGN\ROCKYFLTS\HILL881\OU-1\GRAPHS\PCE 2 DWG




## EXPLANATION

4387 WELL NUMBER

(3600) AVERAGE PCE CONCENTRATION IN ppb

NOTE Concentrations in ppb unless otherwise labeled

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Rocky Flats Environmental Technology Site
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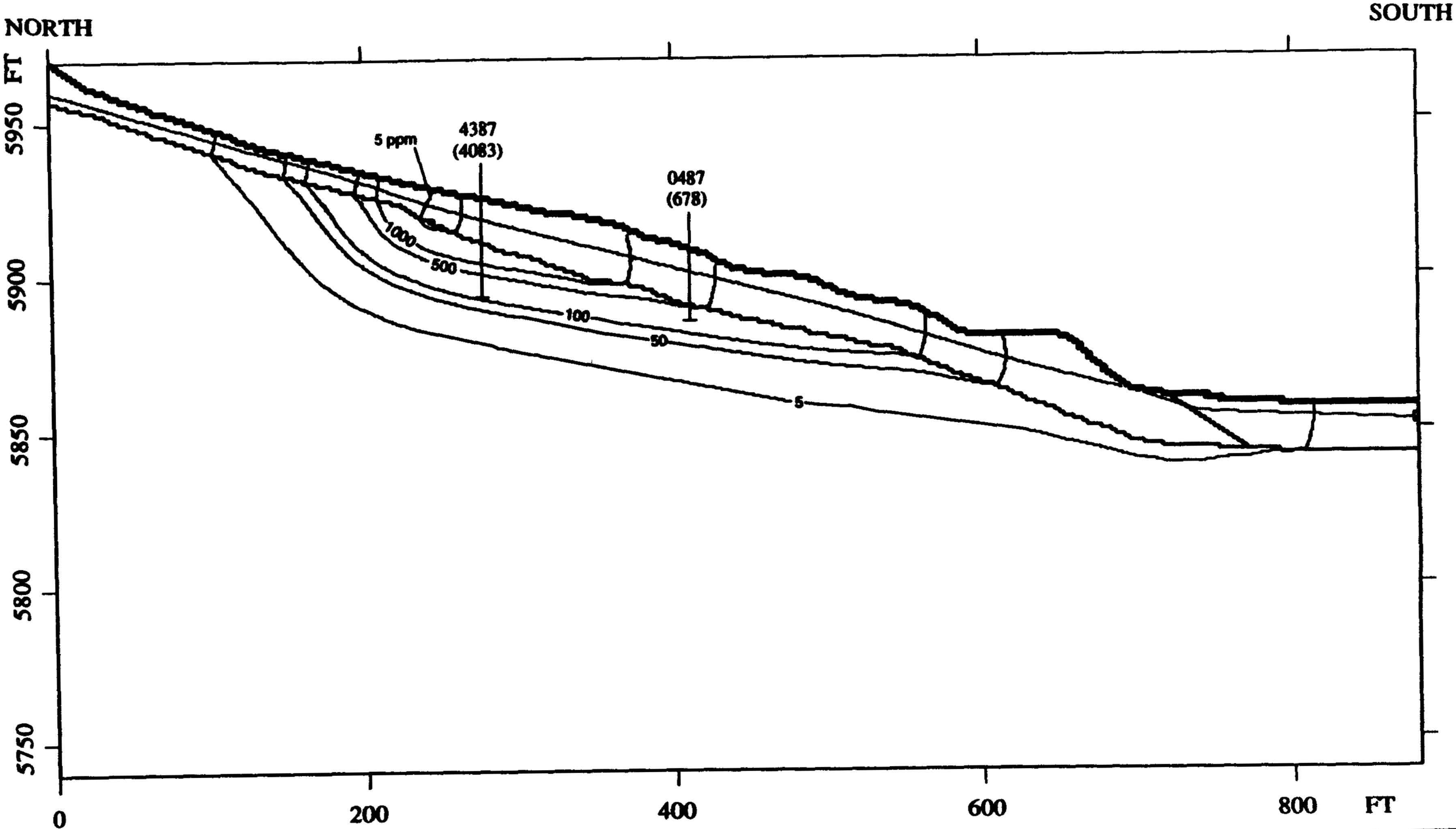
OPERABLE UNIT NO 1

**CONCENTRATION CONTOURS OF PCE**
**TIME = 9125 DAYS (1994)**

**Figure B-21**

K:\DESIGN YFLTS\HILL881\OU-1\GRAPHS\PCE-5 DWG




EXPLANATION

4387 WELL NUMBER

(3600) AVERAGE PCE CONCENTRATION IN ppb

NOTE Concentrations in ppb unless otherwise labeled

U S DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

CONCENTRATION CONTOURS OF PCE
TIME = 146000 DAYS (2369)

Figure B 22

## Simulated concentration of 1,1 DCE down gradient of the French drain

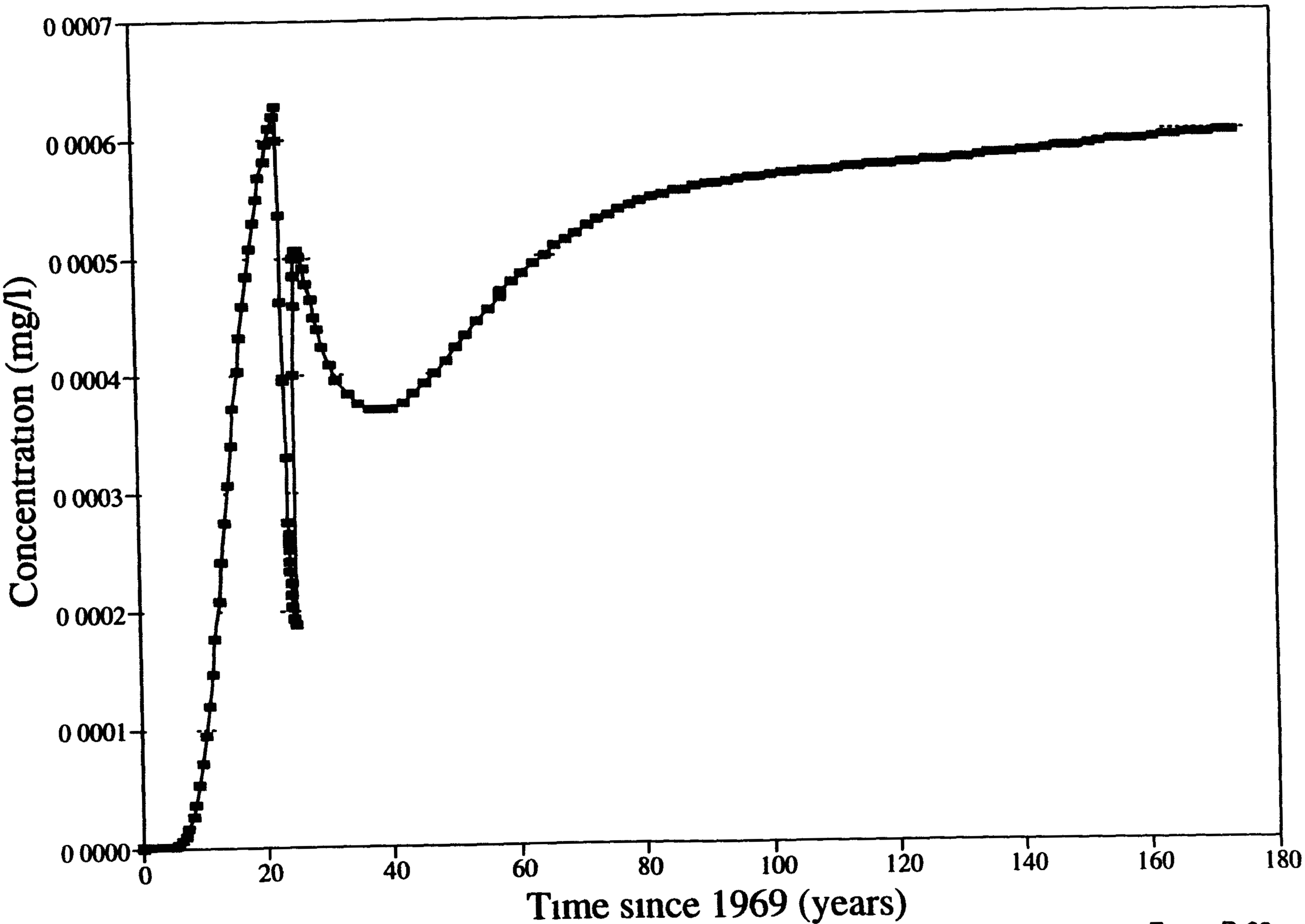



Figure B 23

## Simulated concentration of 1,1 DCE at Woman creek

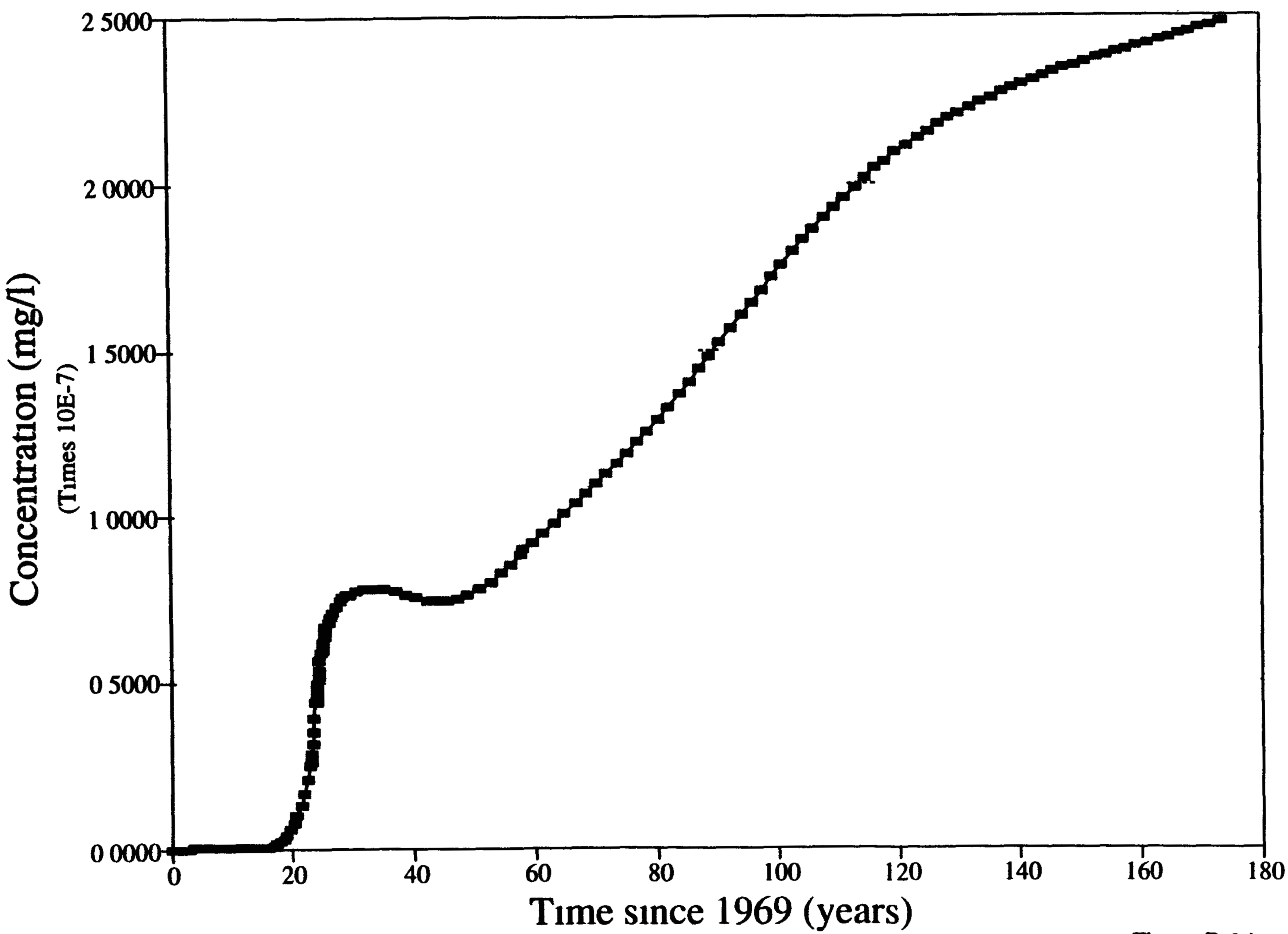



Figure B-24

Simulated concentration of PCE
down gradient of the French drain

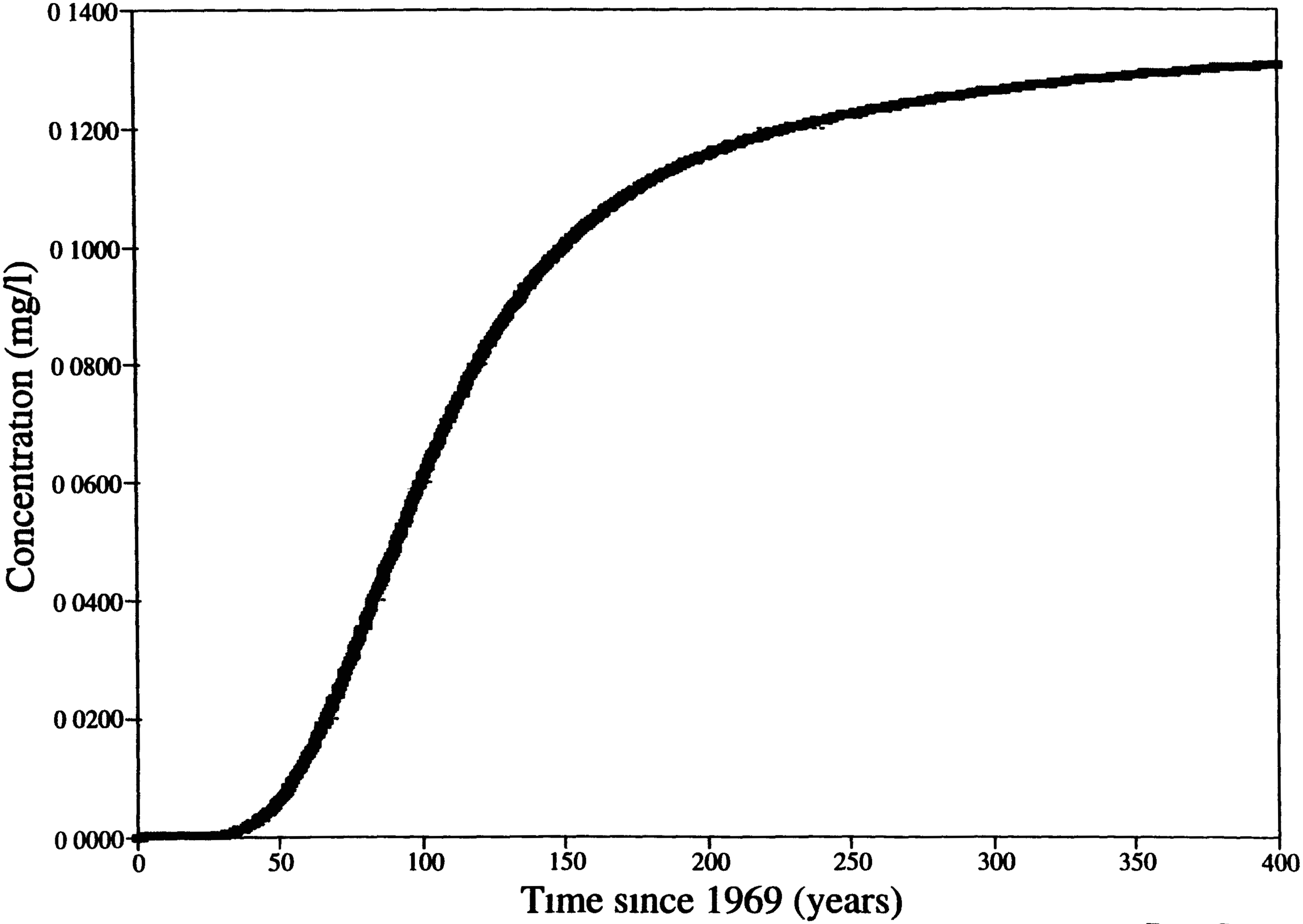



Figure B 25

Simulated concentration of PCE
at Woman creek

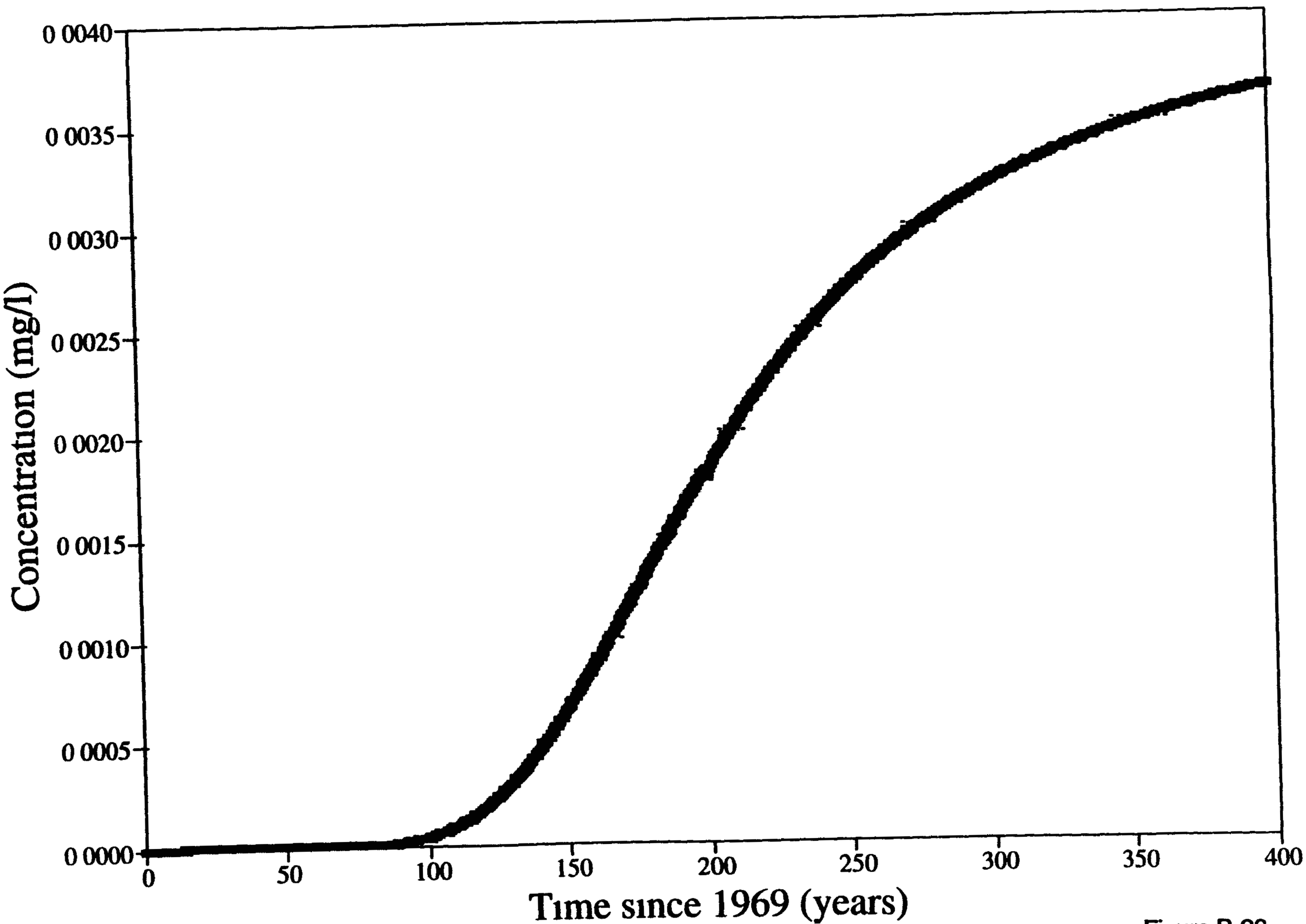



Figure B 26

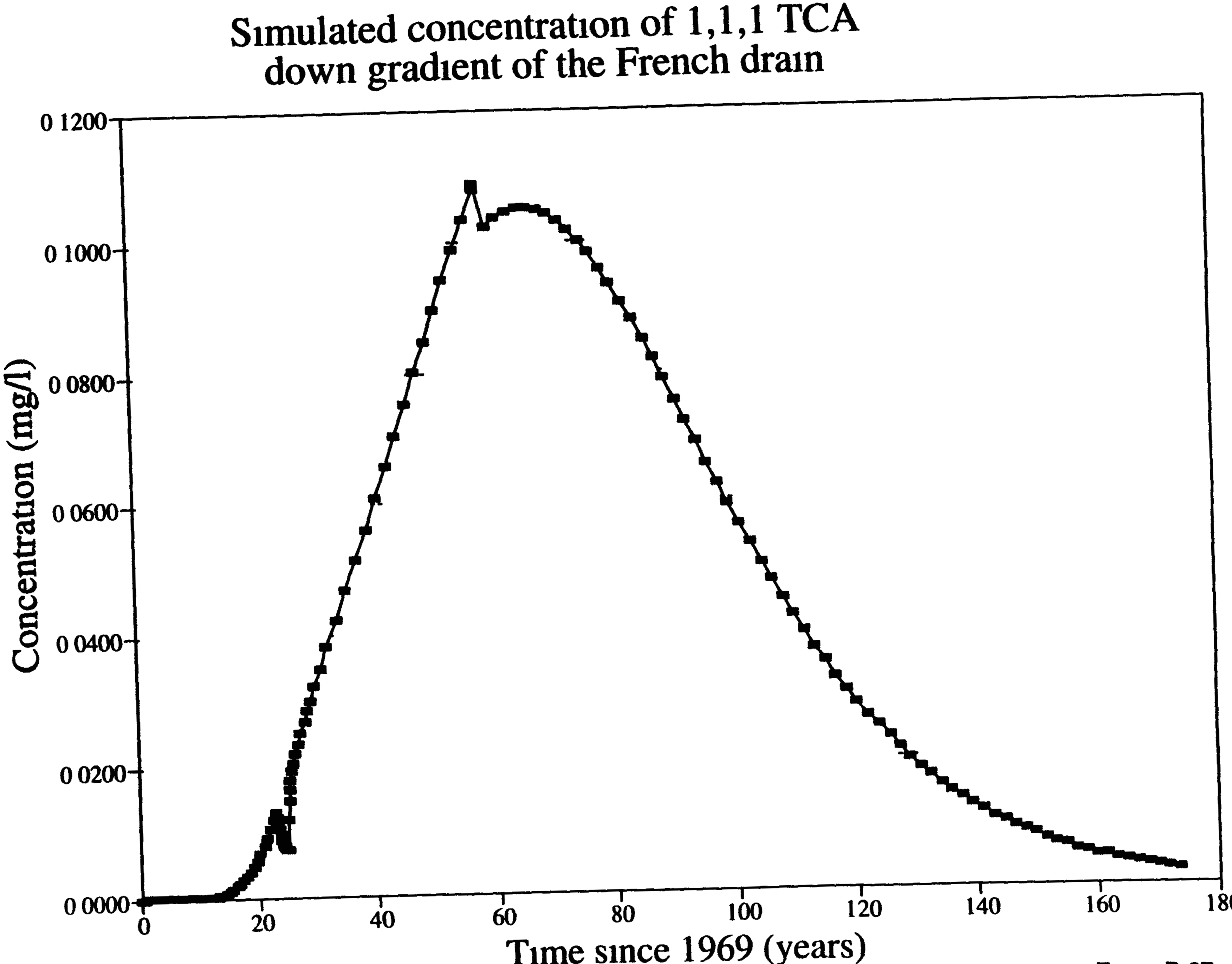

Simulated concentration of 1,1,1 TCA
down gradient of the French drain
Concentration (mg/l)
0 1200
0 1000
0 0800
0 0600
0 0400
0 0200
0 0000
0
20
40
60
80
100
120
140
160
180
Time since 1969 (years)

Figure B-27

Simulated concentration of 1,1,1 TCA at Woman creek

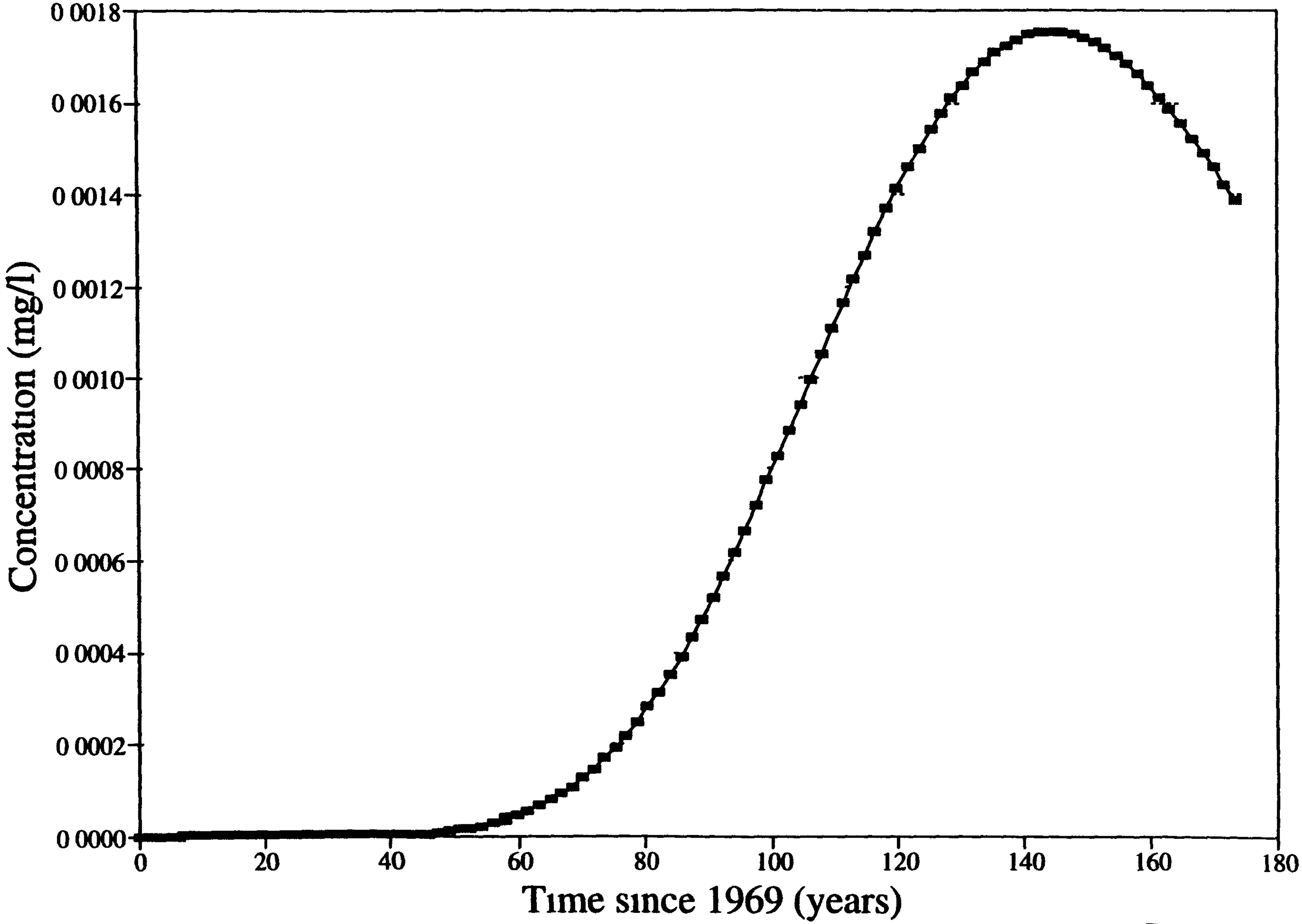



Figure B 28

## Simulated concentration of CCL4 down gradient of the French drain

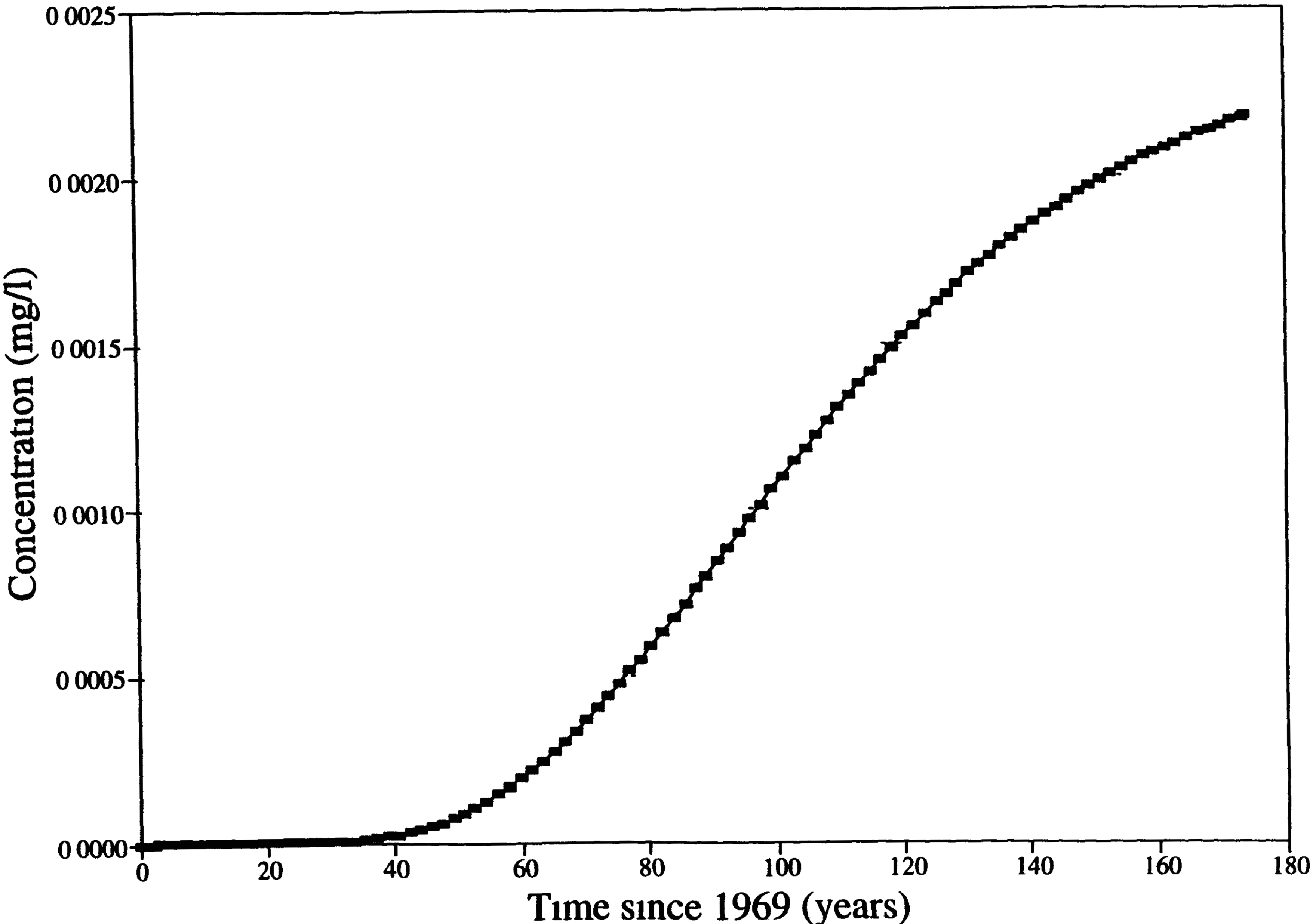



Figure B-29

# Simulated concentration of CCL4 at Woman creek

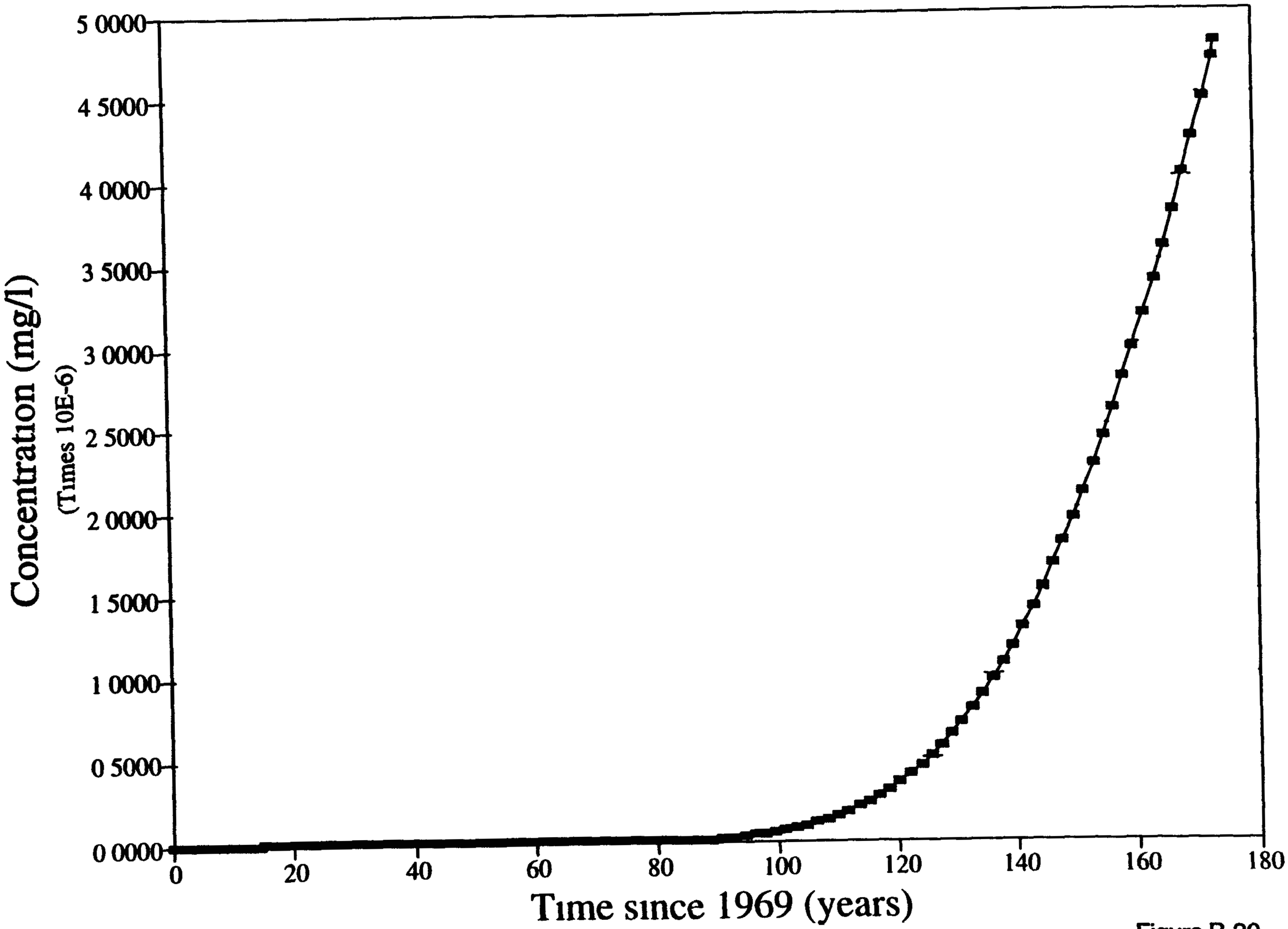



Figure B 30

## Simulated concentration of Selenium down gradient of the French drain

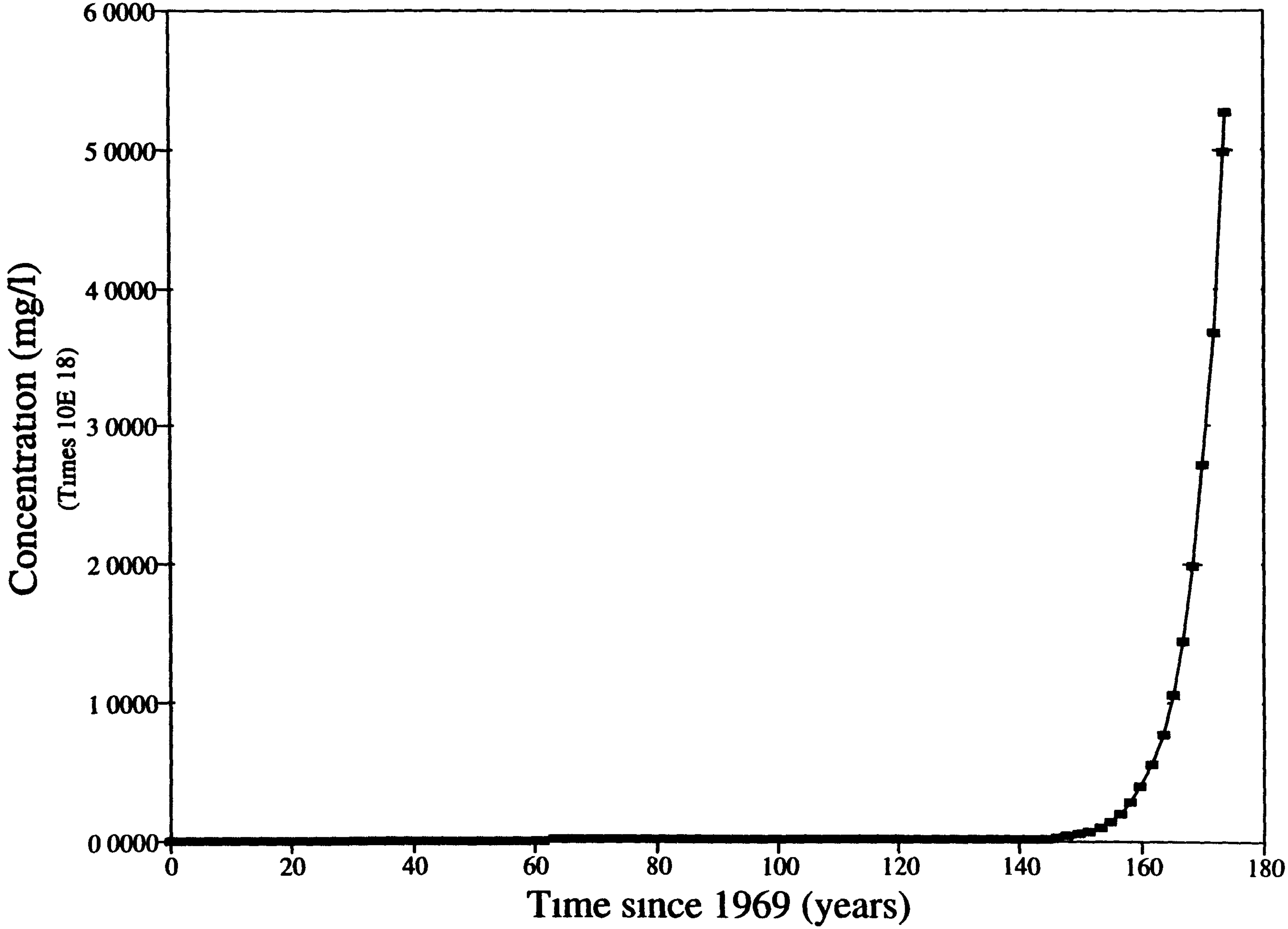



Figure B 31

## Simulated concentration of Selenium at Woman creek

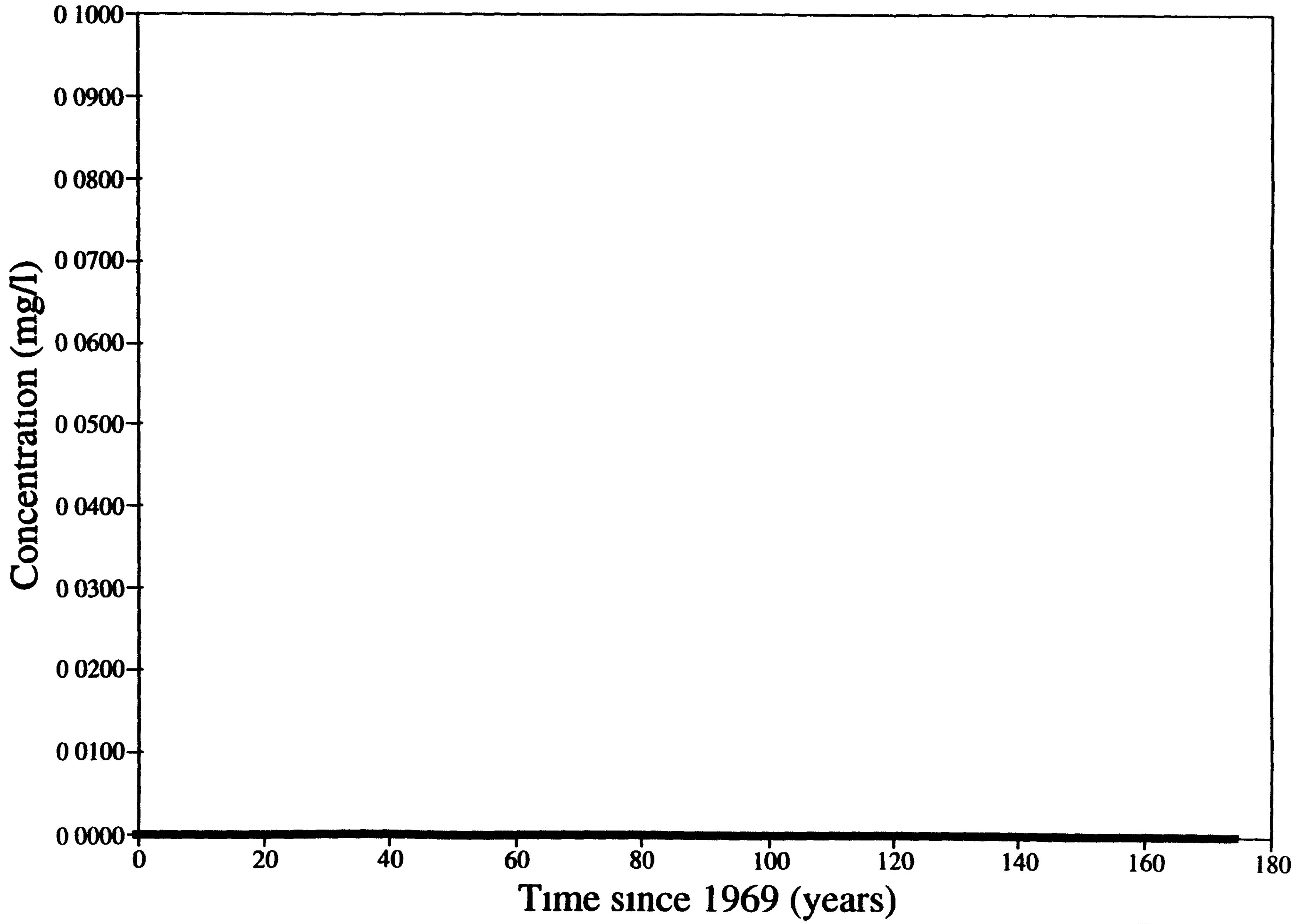
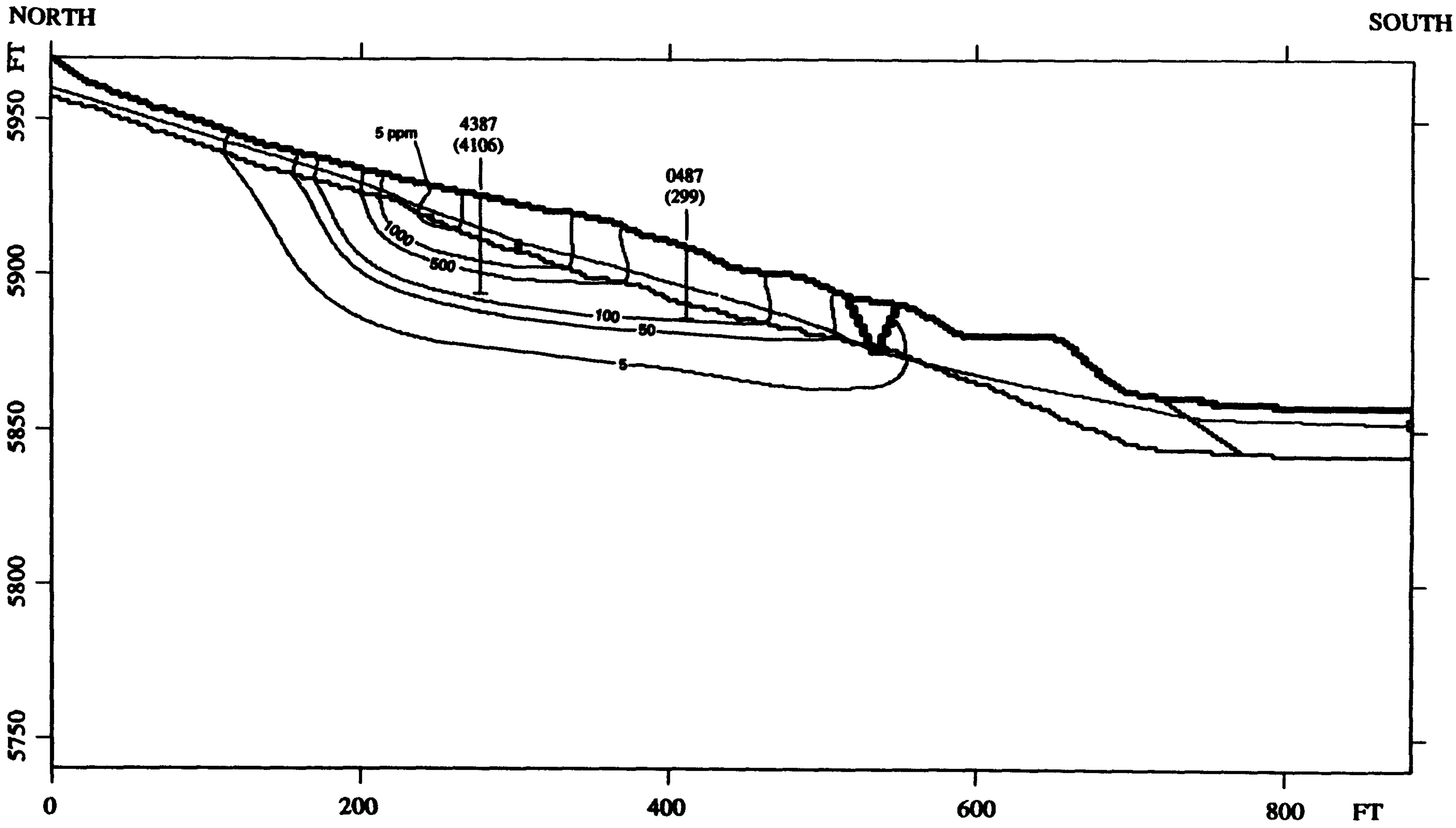



Figure B-32

K:\DESIGN\- YFLTS\HILL881\OU-1\GRAPHS\PCE-4.DWG




## EXPLANATION

4387 WELL NUMBER

(3600) AVERAGE PCE CONCENTRATION IN ppb

NOTE. Concentrations in ppb unless otherwise labeled

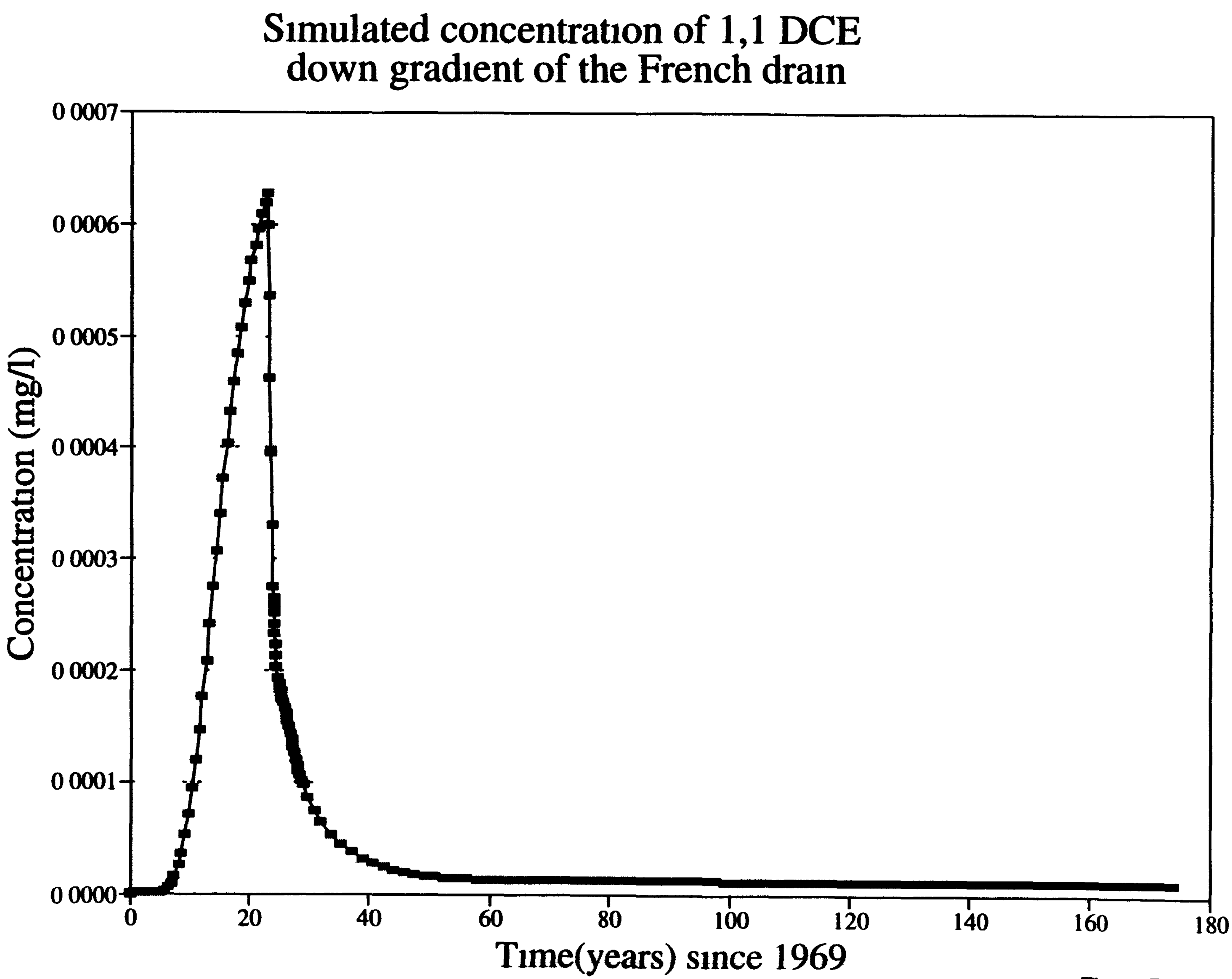
**U S DEPARTMENT OF ENERGY**

Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

**CONCENTRATION CONTOURS OF PCE**
**TIME = 146000 DAYS (2369)**

**Figure B-33**



Simulated concentration of 1,1 DCE
down gradient of the French drain
Concentration (mg/l)
0 0007
0 0006
0 0005
0 0004
0 0003
0 0002
0 0001
0 0000
0
20
40
60
80
100
120
140
160
180
Time(years) since 1969


Figure B-34

Simulated concentration of 1,1 DCE
at Woman creek

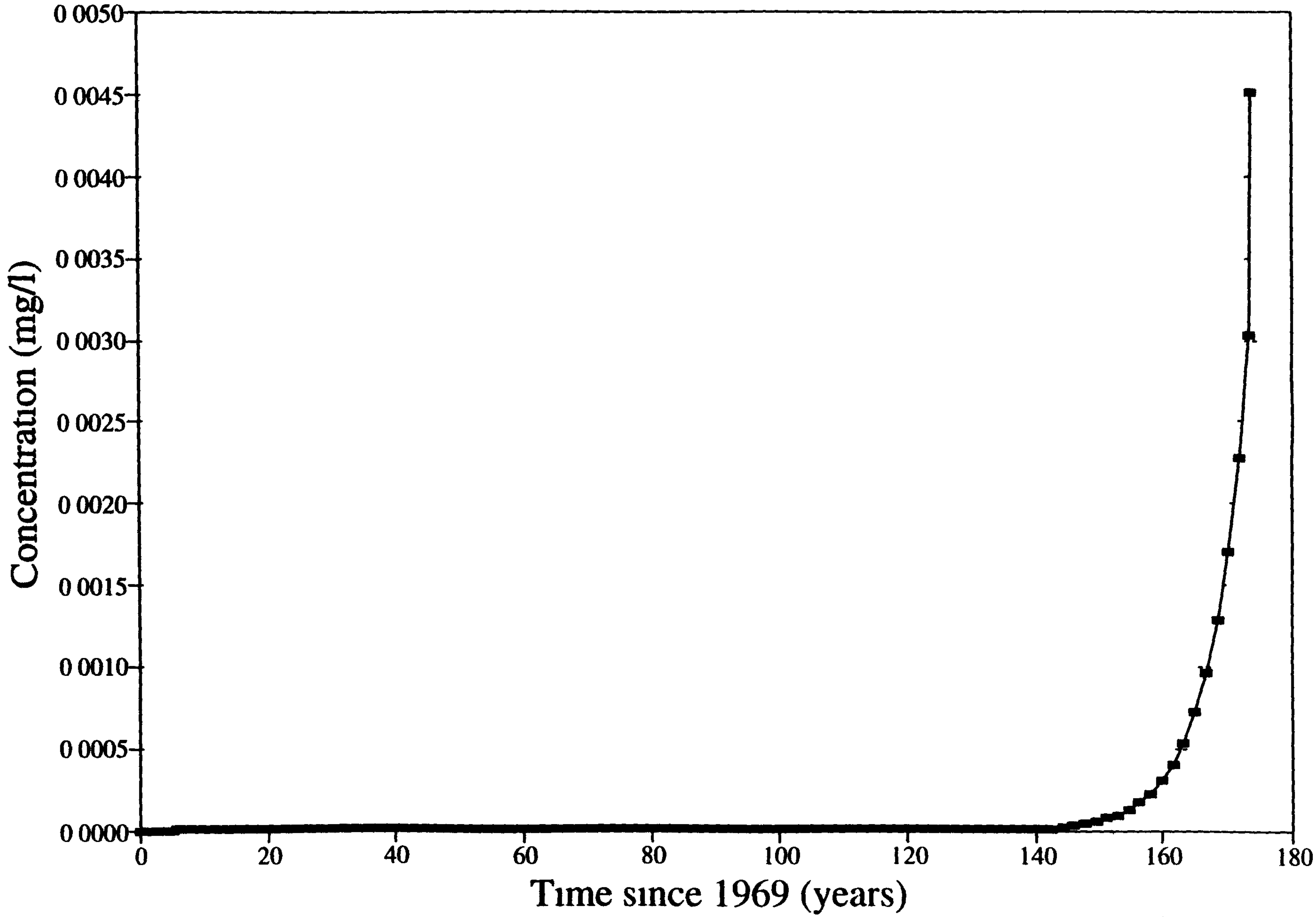



Figure B 35

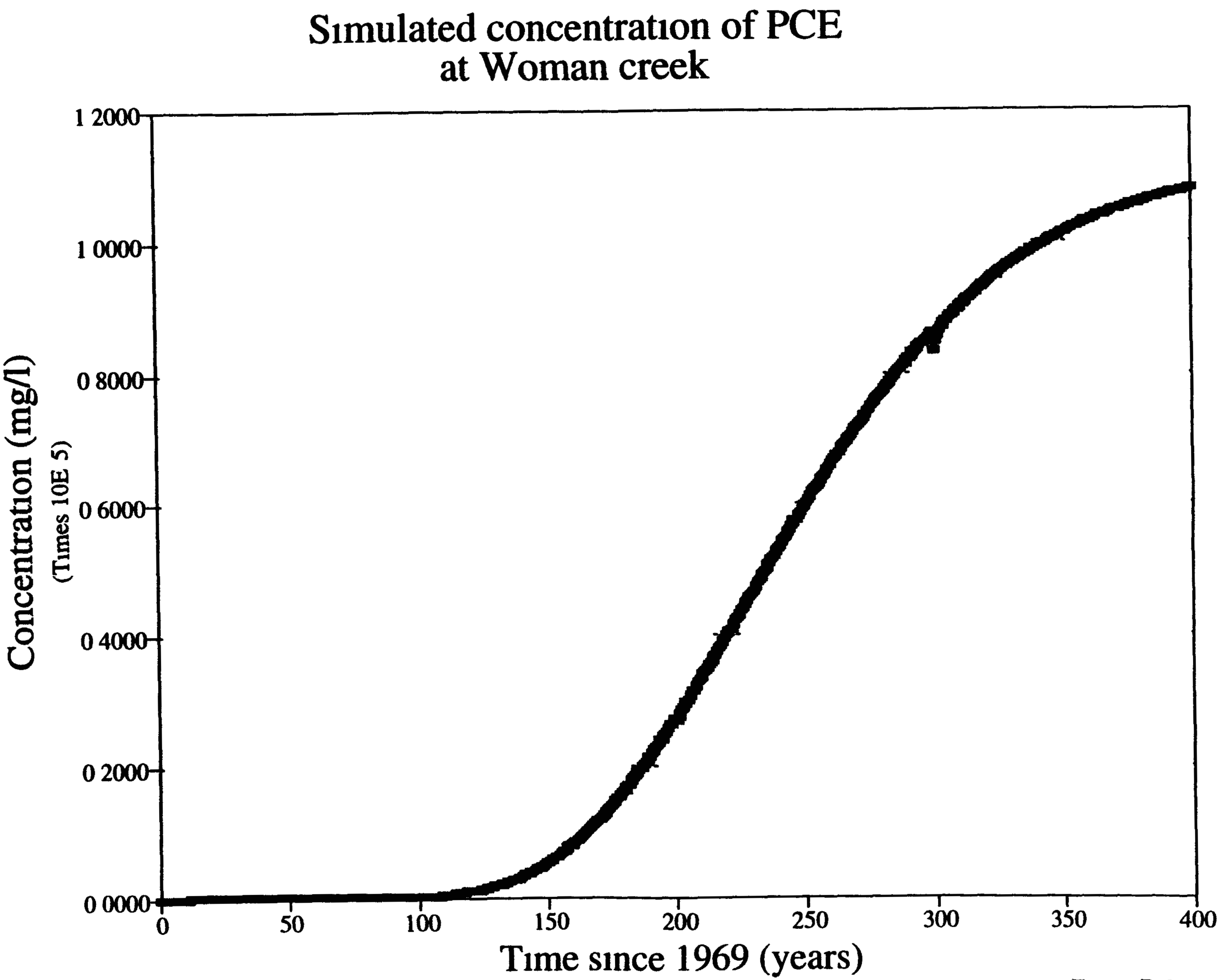

Simulated concentration of PCE
at Woman creek
Concentration (mg/l)
(Times 10E 5)
1 2000
1 0000
0 8000
0 6000
0 4000
0 2000
0 0000
0
50
100
150
200
250
300
350
400
Time since 1969 (years)

Figure B 37

Simulated concentration of 1,1,1 TCA down gradient of the French drain

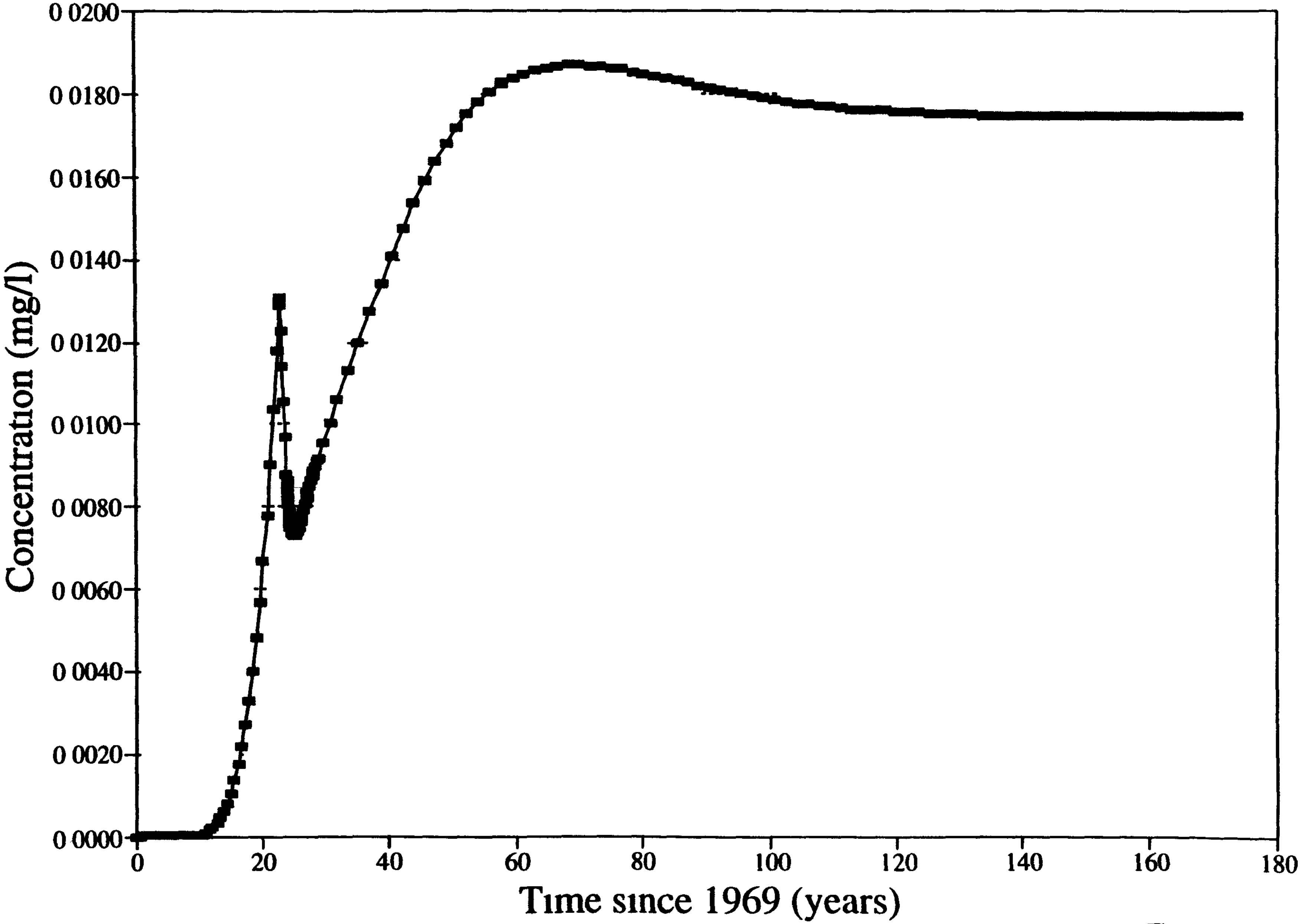



Figure B-38

## Simulated concentration of 1,1,1 TCA at Woman creek

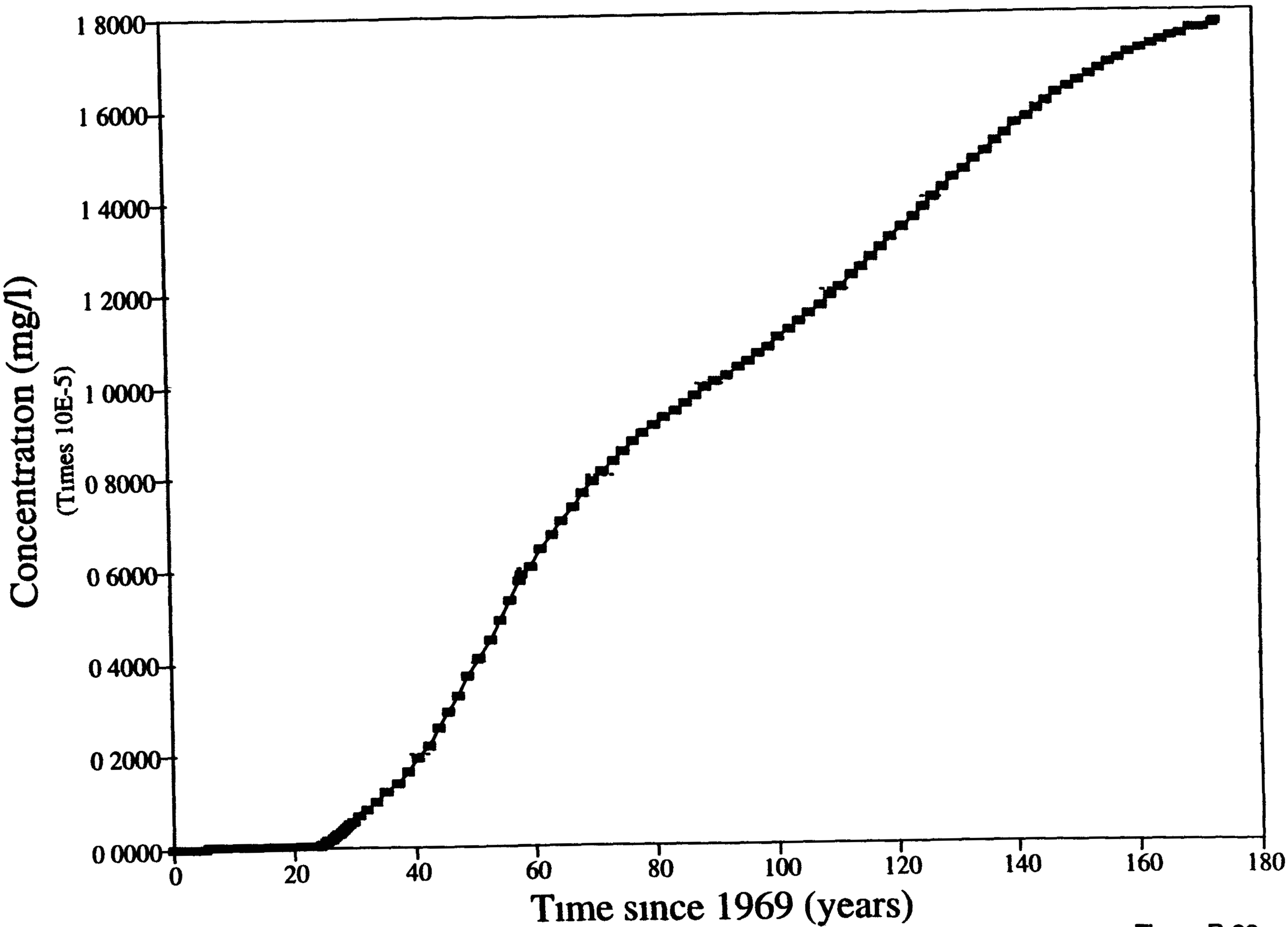



Figure B-39

Simulated concentration of CCL4
down gradient of the French drain

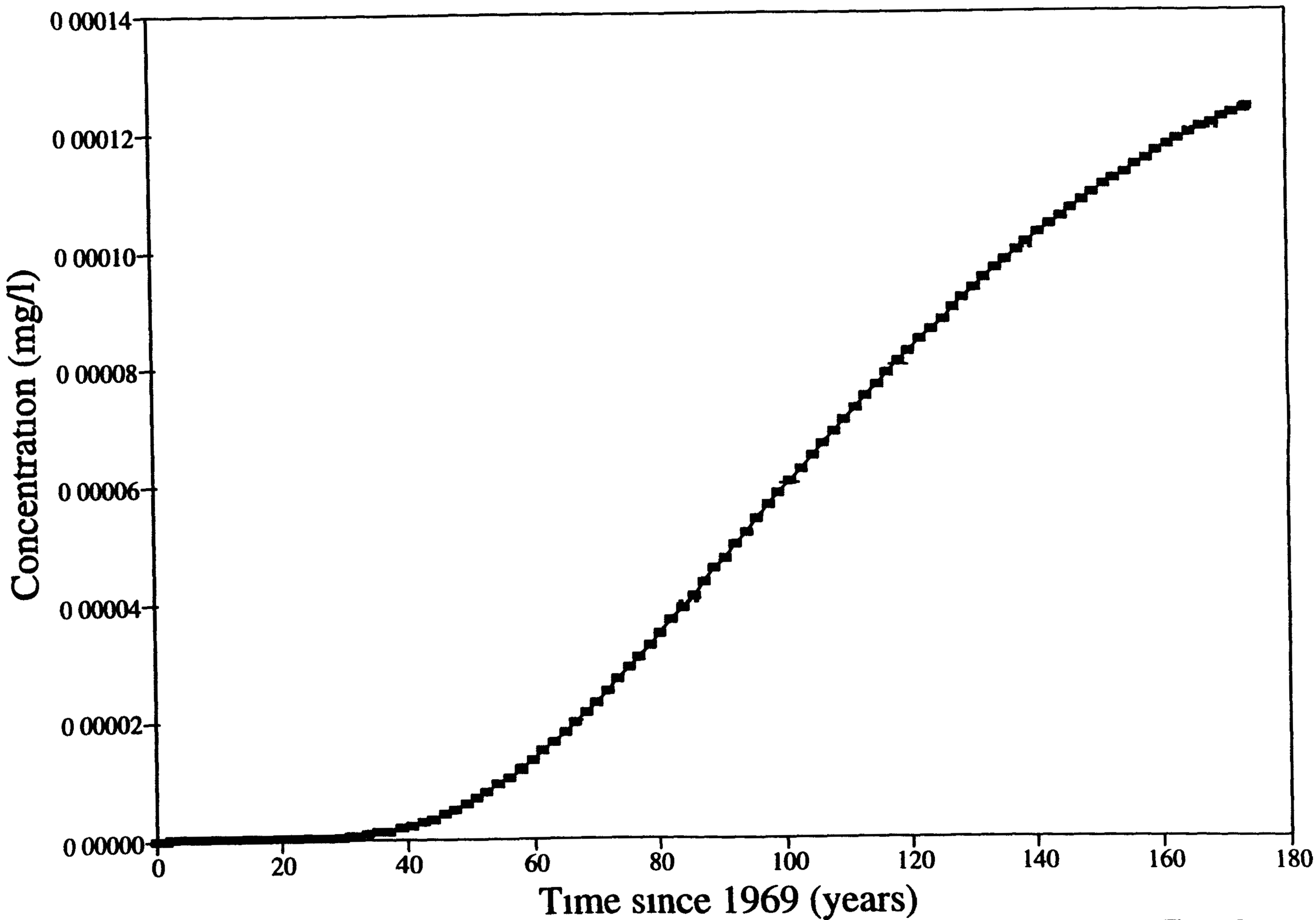



Figure B-40

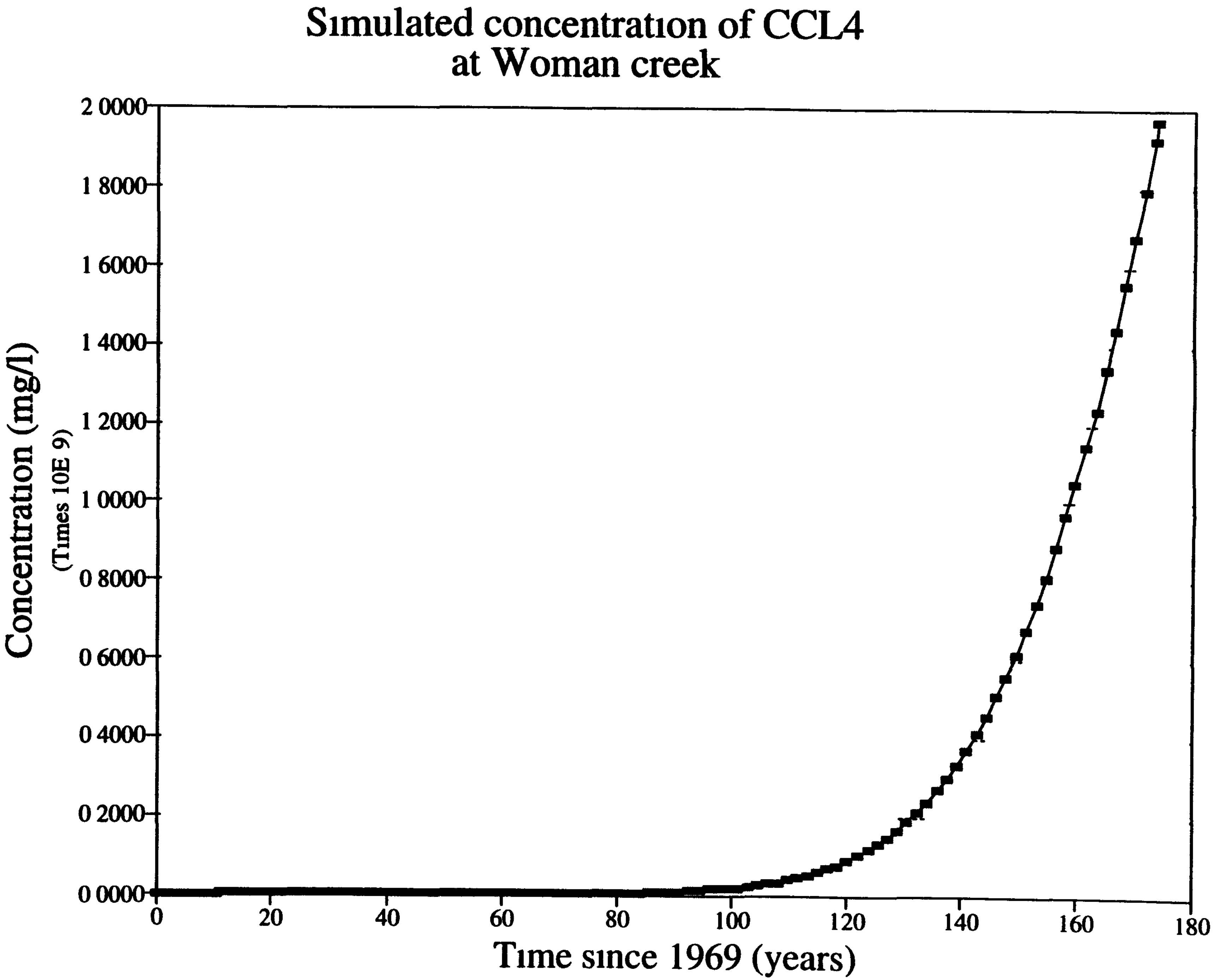

Simulated concentration of CCL4
at Woman creek
Concentration (mg/l)
(Times 10E 9)
2 0000
1 8000
1 6000
1 4000
1 2000
1 0000
0 8000
0 6000
0 4000
0 2000
0 0000
0
20
40
60
80
100
120
140
160
180
Time since 1969 (years)

Figure B-41

## Simulated concentration of Selenium down gradient of the French drain

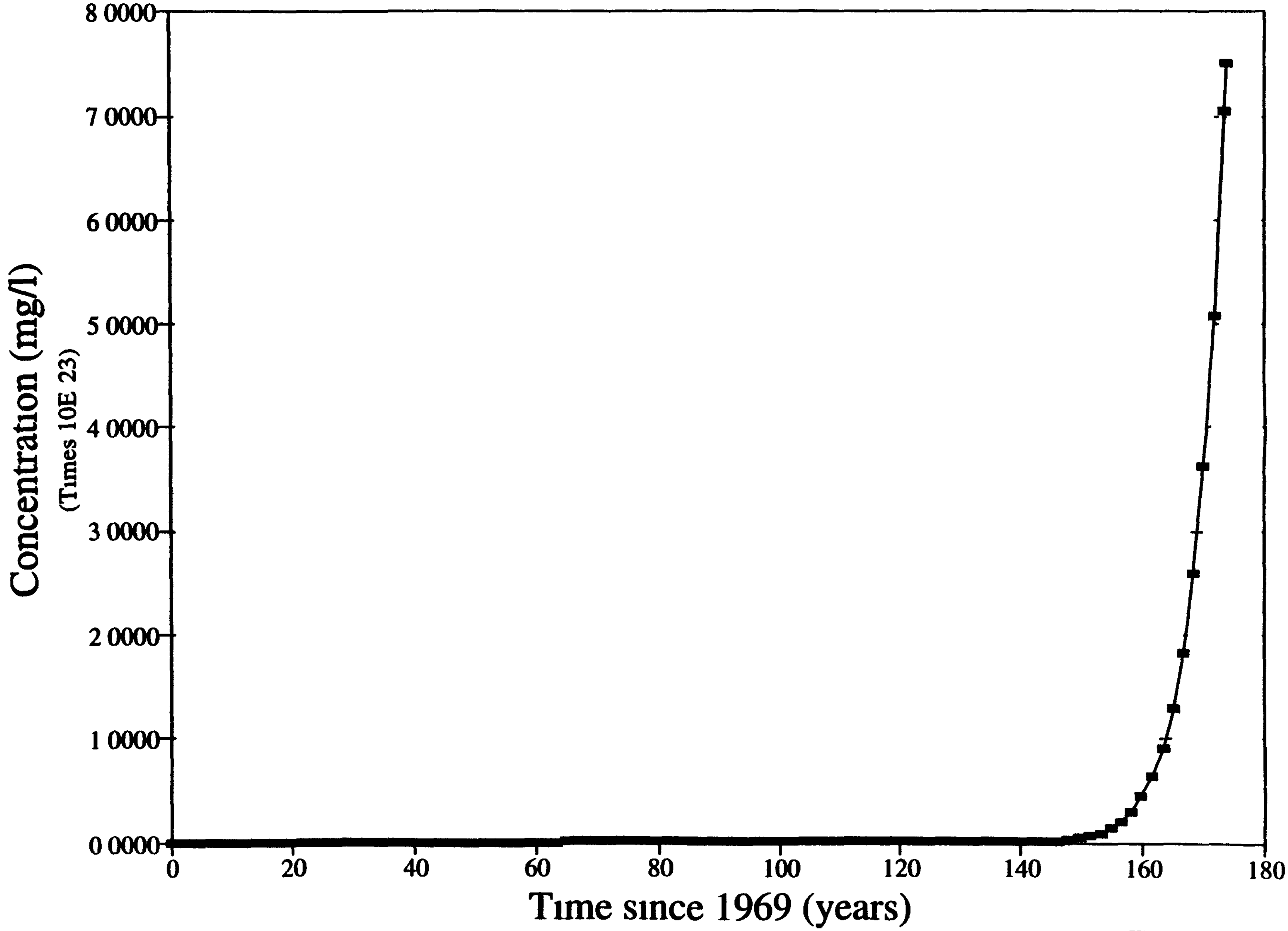



Figure B-42

Simulated concentration of Selenium at Woman creek

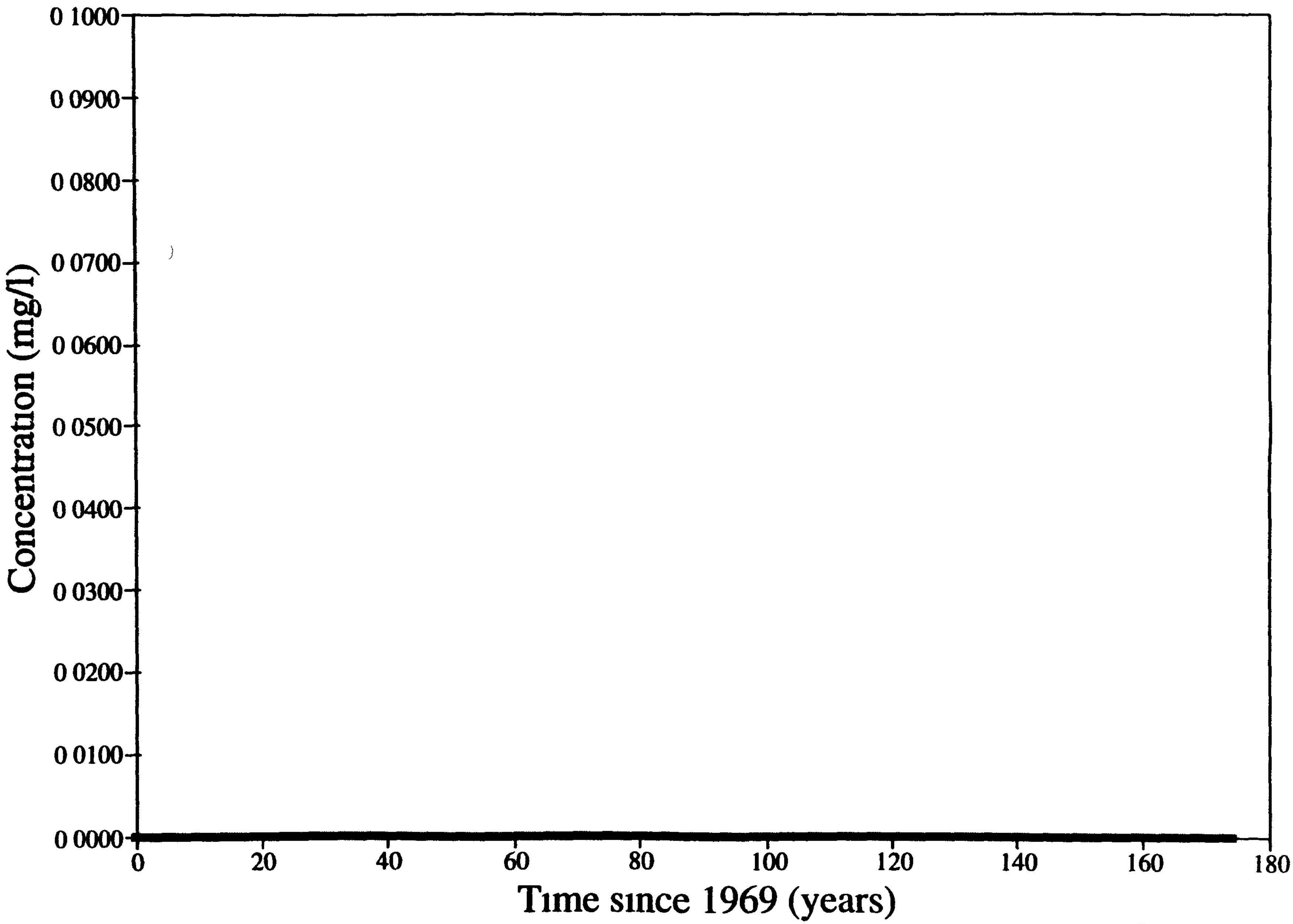
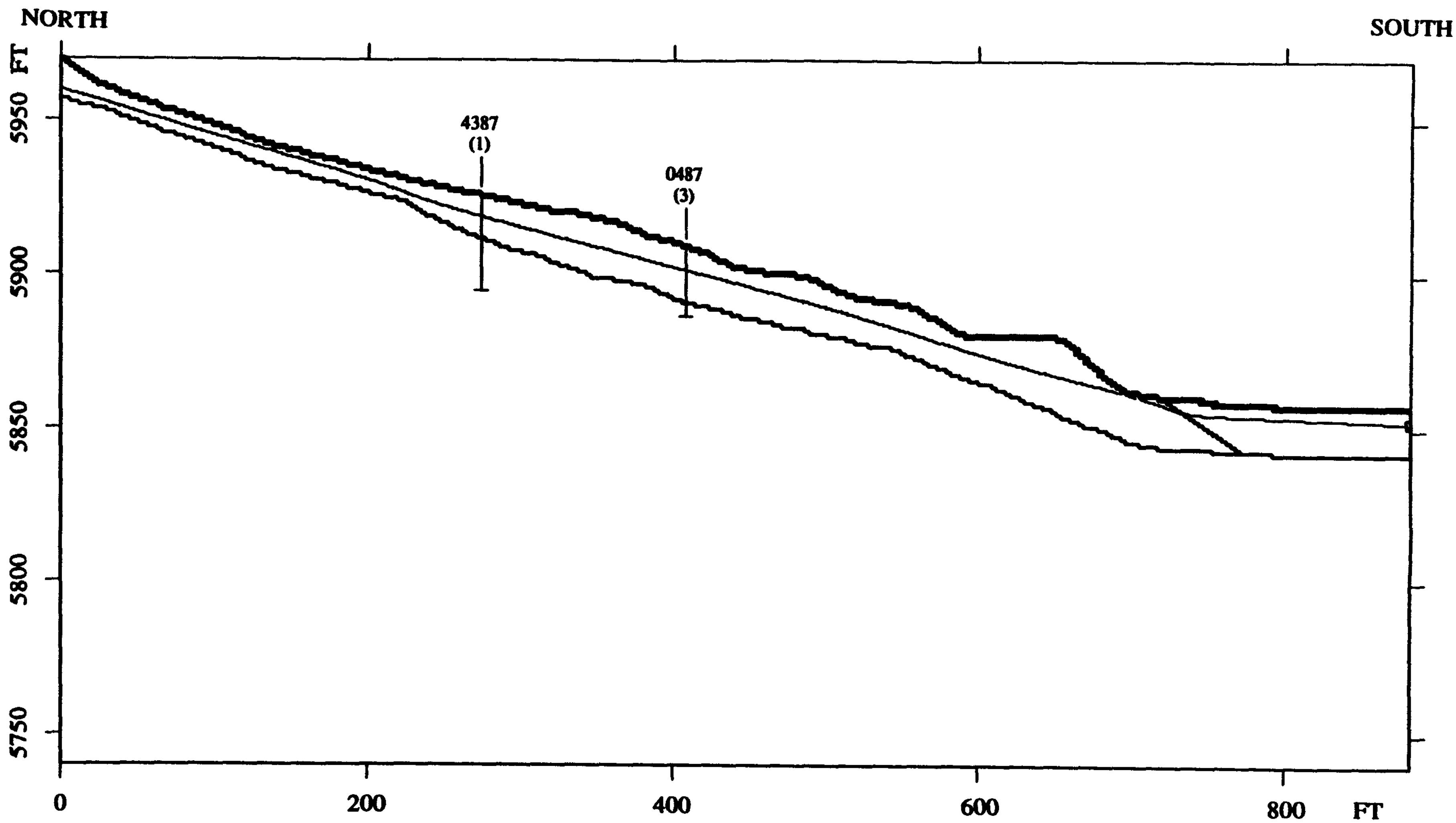



Figure B-43

K:\DESIGN YFLTS\HILL881\OU-1\GRAPHS\PCE-6 DWG




EXPLANATION

4387 WELL NUMBER

(3600) AVERAGE PCE CONCENTRATION IN ppb

NOTE Concentrations in ppb unless otherwise labeled

U S DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

CONCENTRATION CONTOURS
OF PCE
TIME = 73000 DAYS (2169)

Figure B-44

Simulated concentration of 1,1 DCE down gradient of the French drain

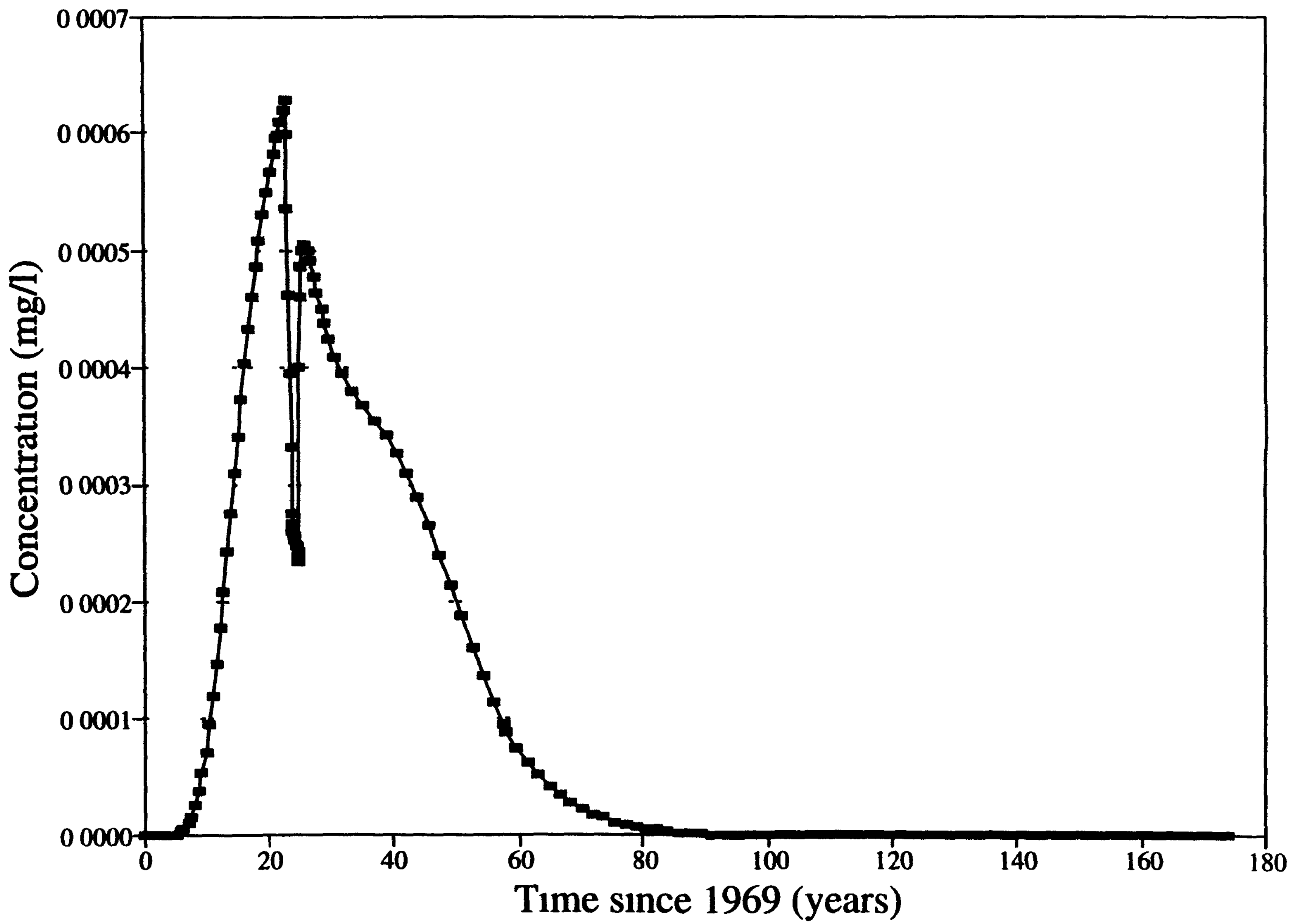



Figure B-45

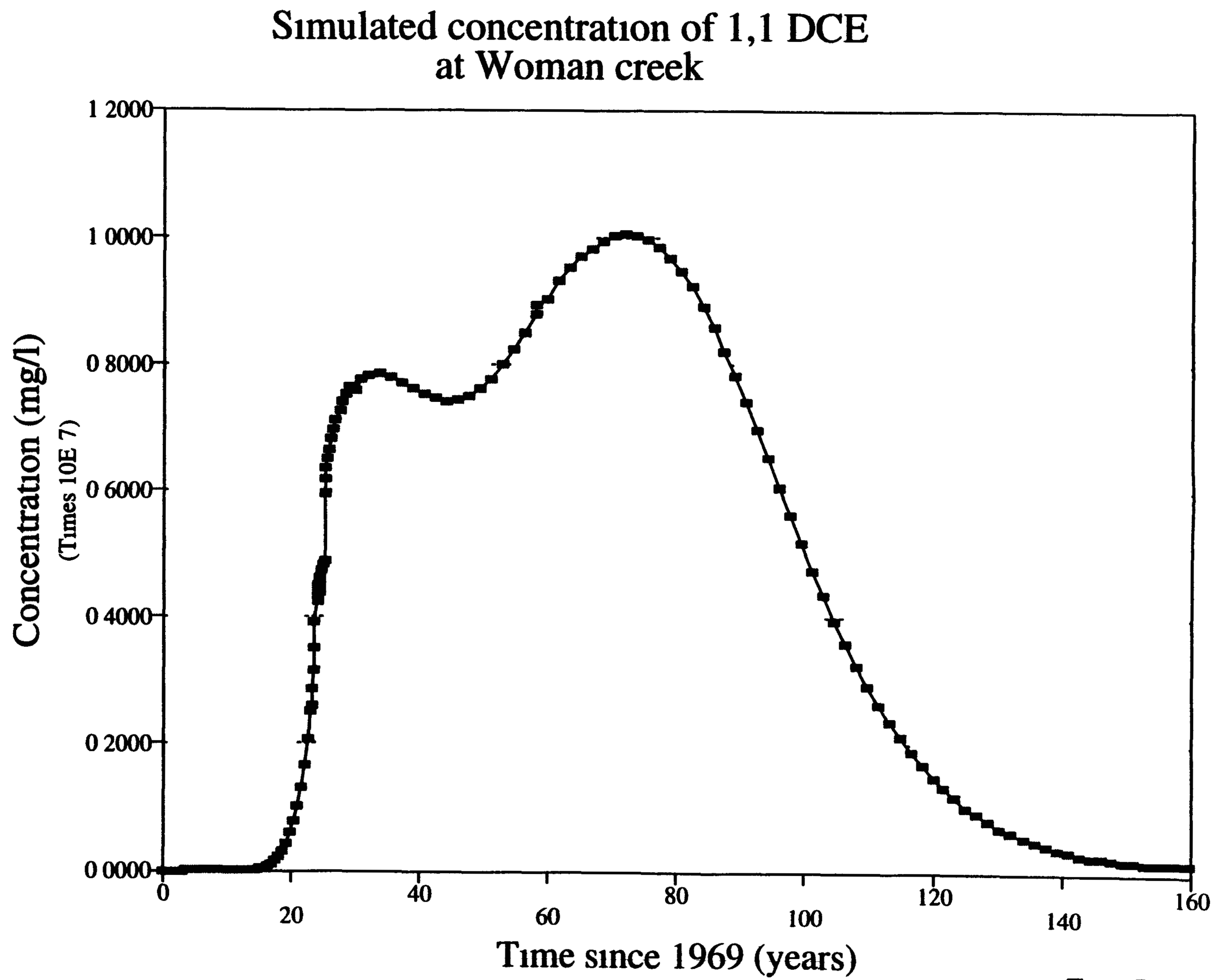

Simulated concentration of 1,1 DCE
at Woman creek
Concentration (mg/l)
(Times 10E 7)
1 2000
1 0000
0 8000
0 6000
0 4000
0 2000
0 0000
0
20
40
60
80
100
120
140
160
Time since 1969 (years)

Figure B-46

# Simulated concentration of PCE down gradient of the French drain

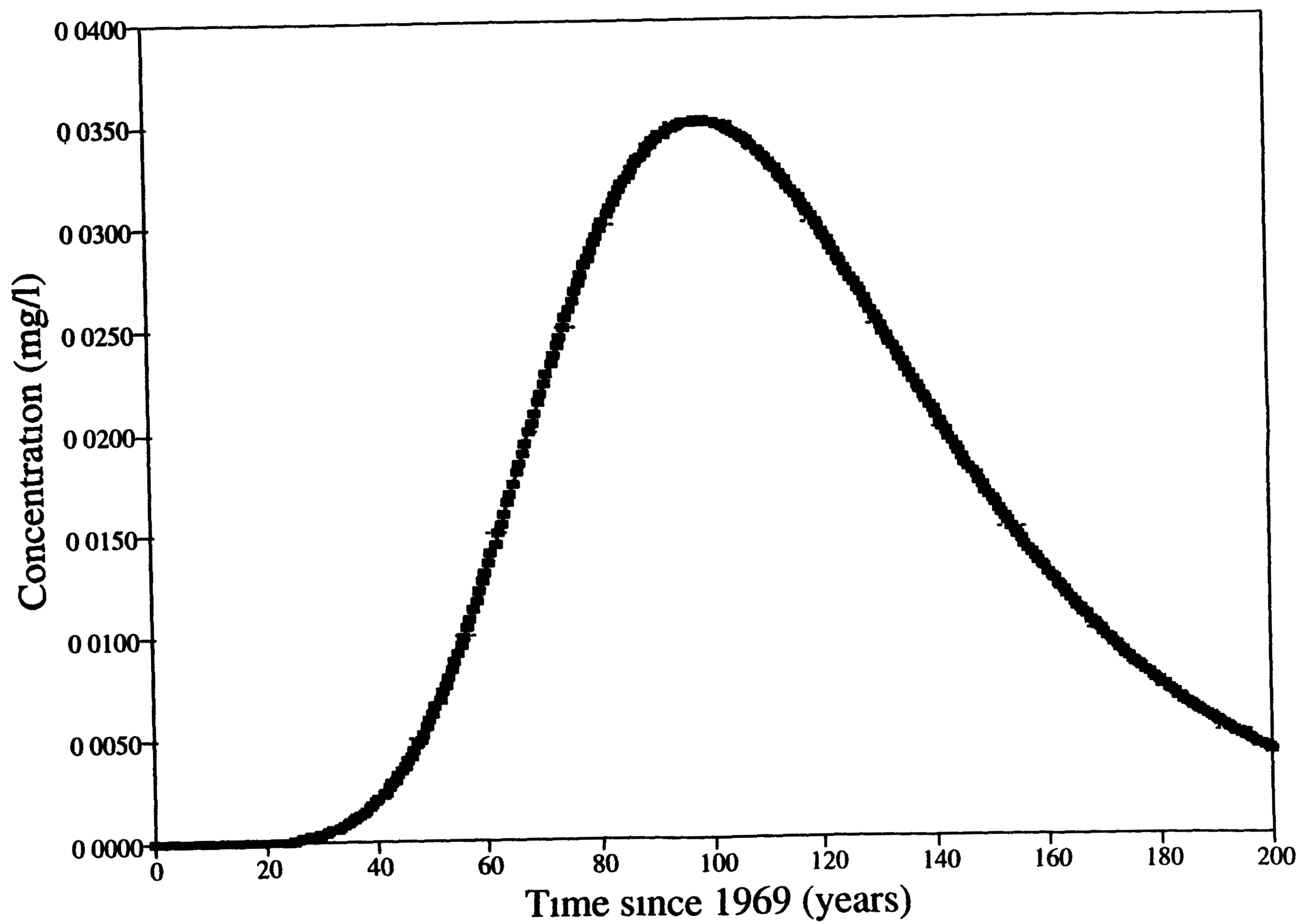



Figure B-47

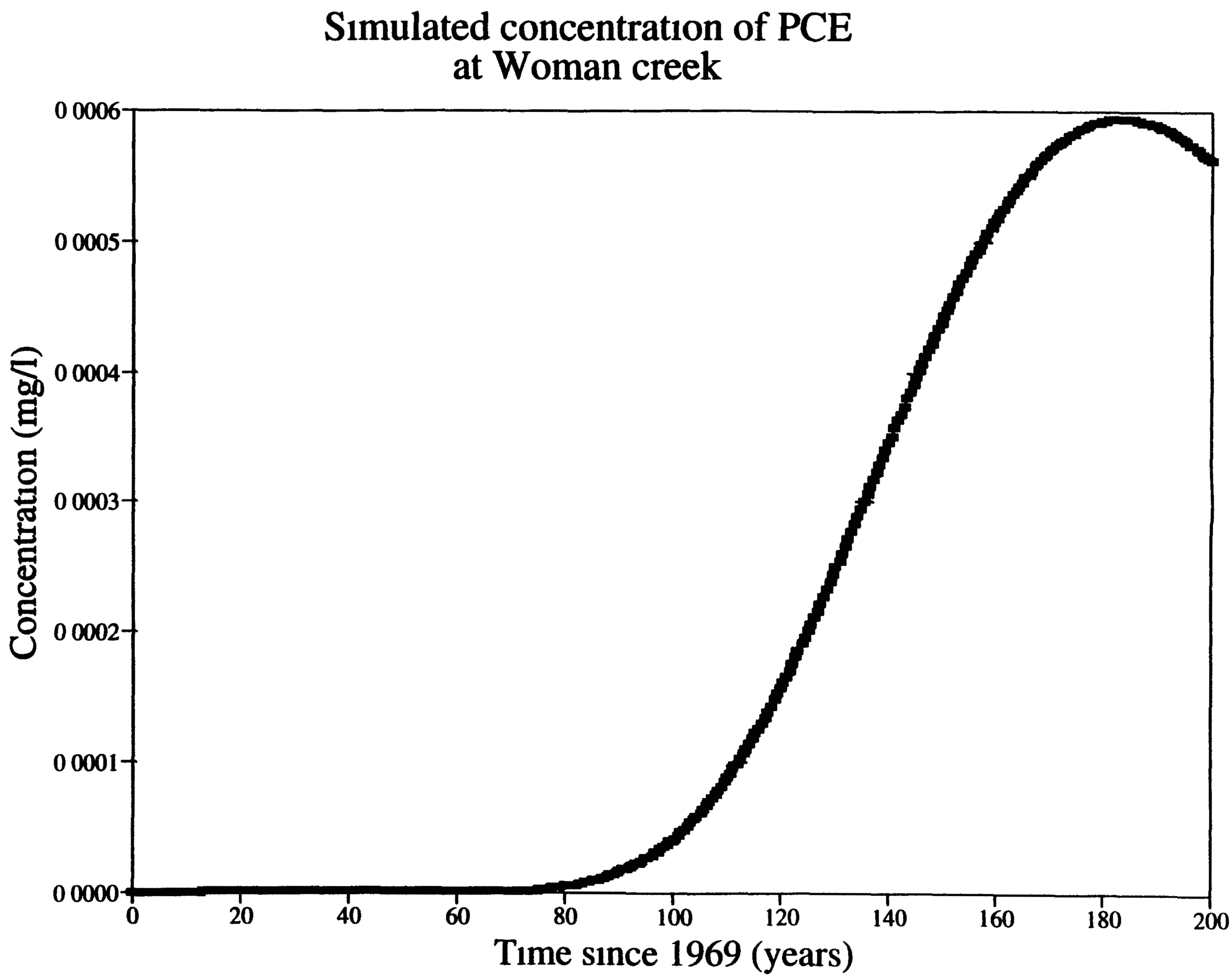

Simulated concentration of PCE
at Woman creek
0 0006
0 0005
0 0004
0 0003
0 0002
0 0001
0 0000
Concentration (mg/l)
0
20
40
60
80
100
120
140
160
180
200
Time since 1969 (years)

Figure B-48

## Simulated concentration of 1,1,1 TCA down gradient of the French drain

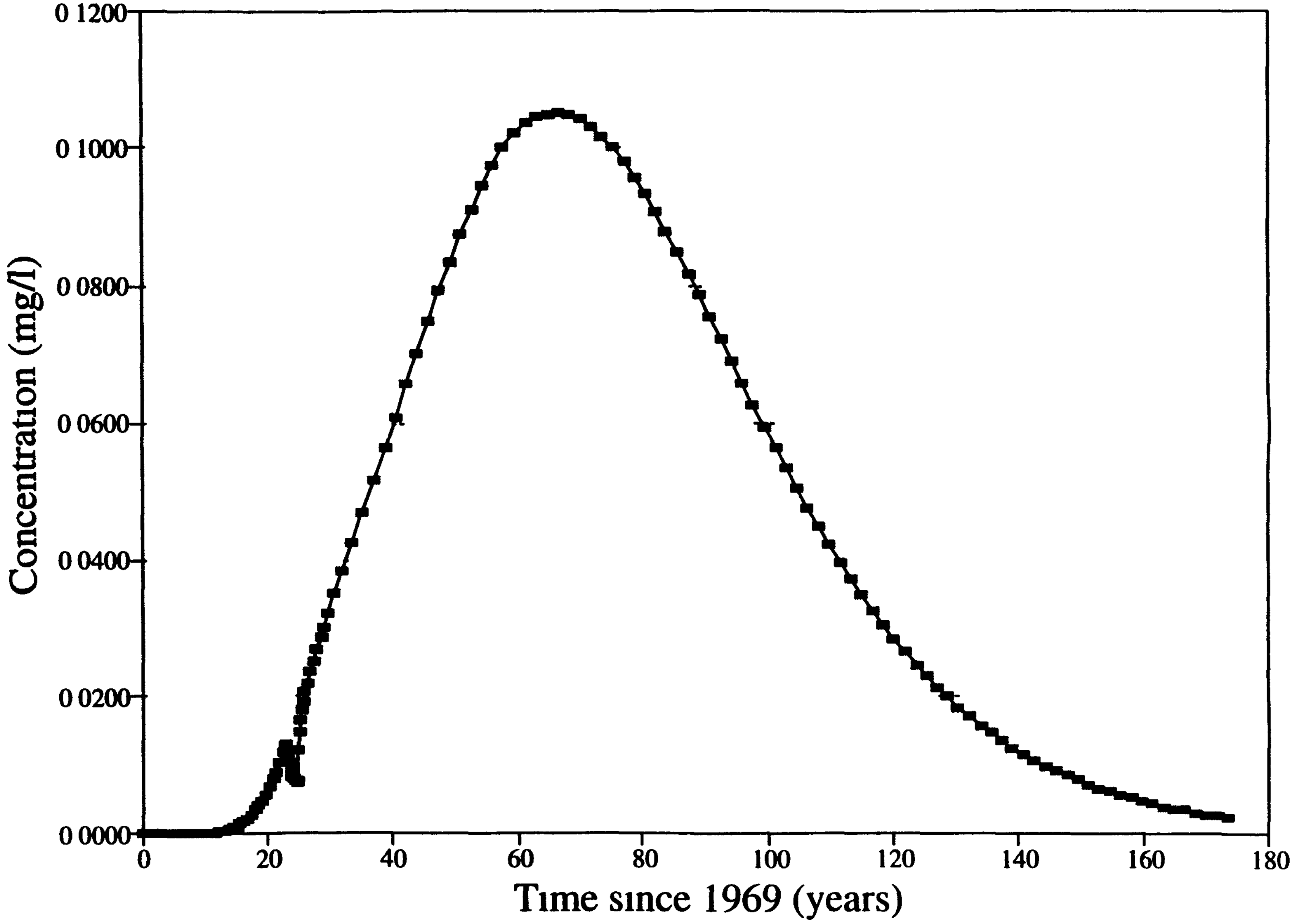



Figure B-49

## Simulated concentration of 1,1,1 TCA at Woman creek

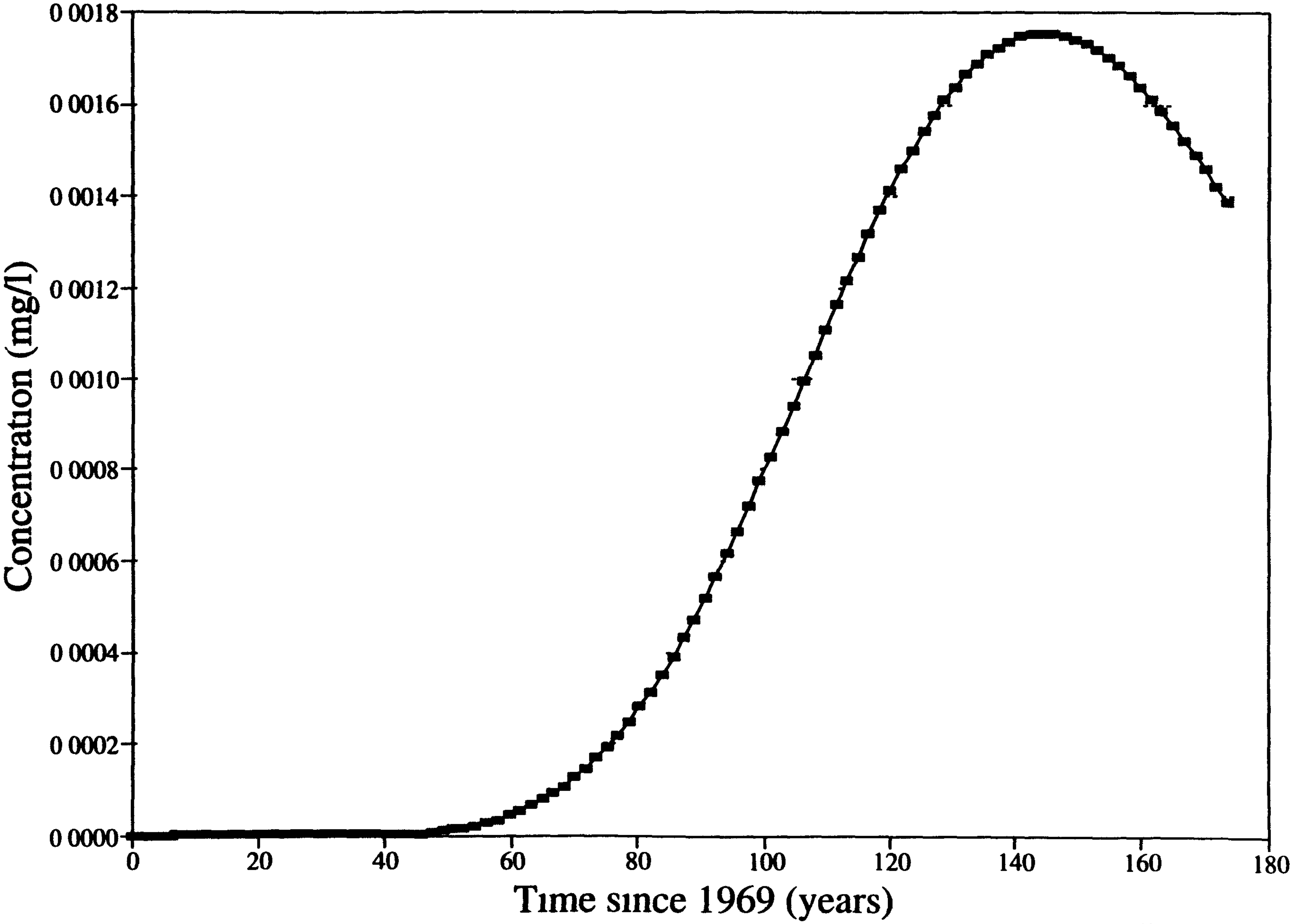



Figure B 50

## Simulated concentration of CCL4 down gradient of the French drain

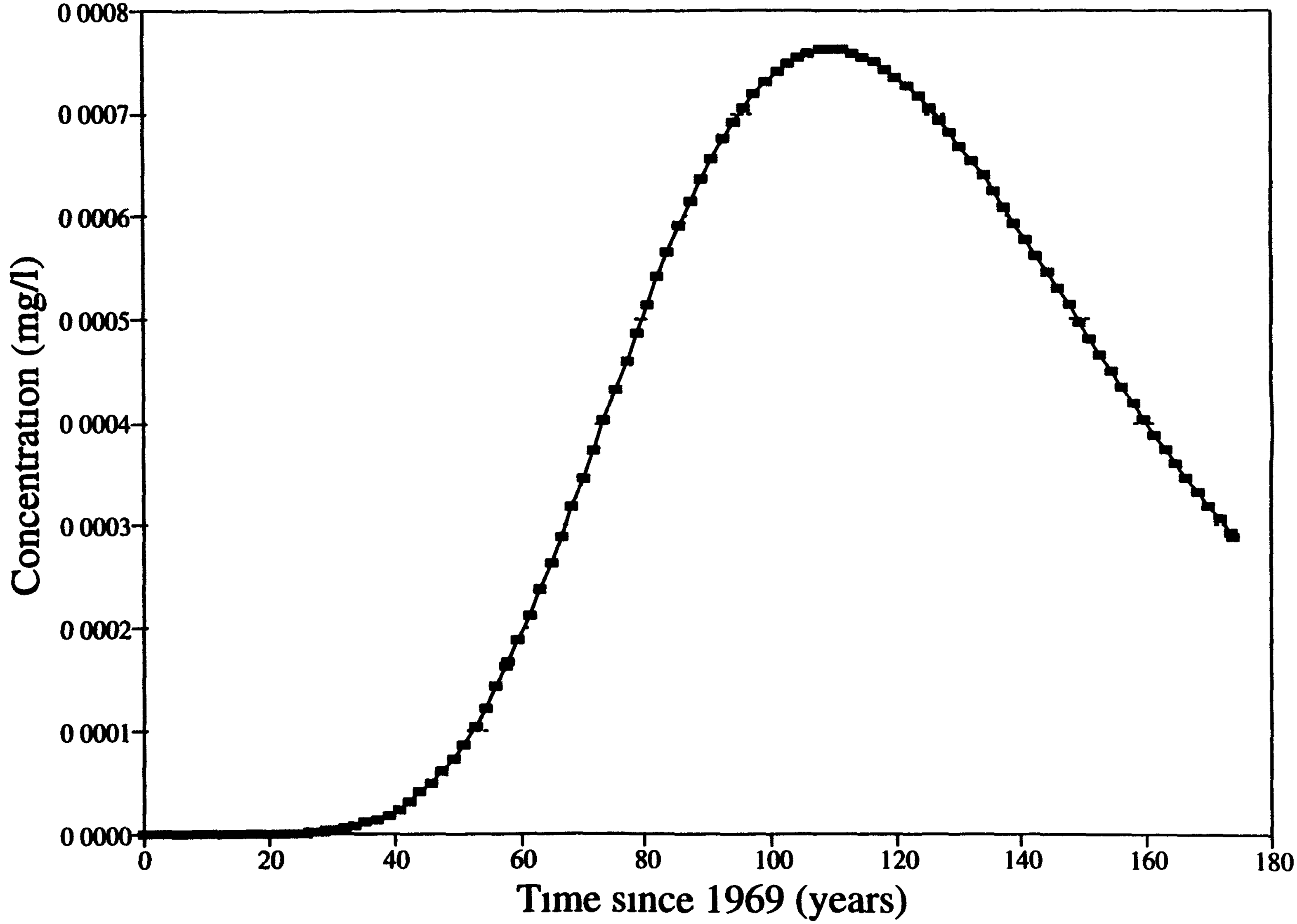



Figure B 51

# Simulated concentration of CCL4 at Woman creek

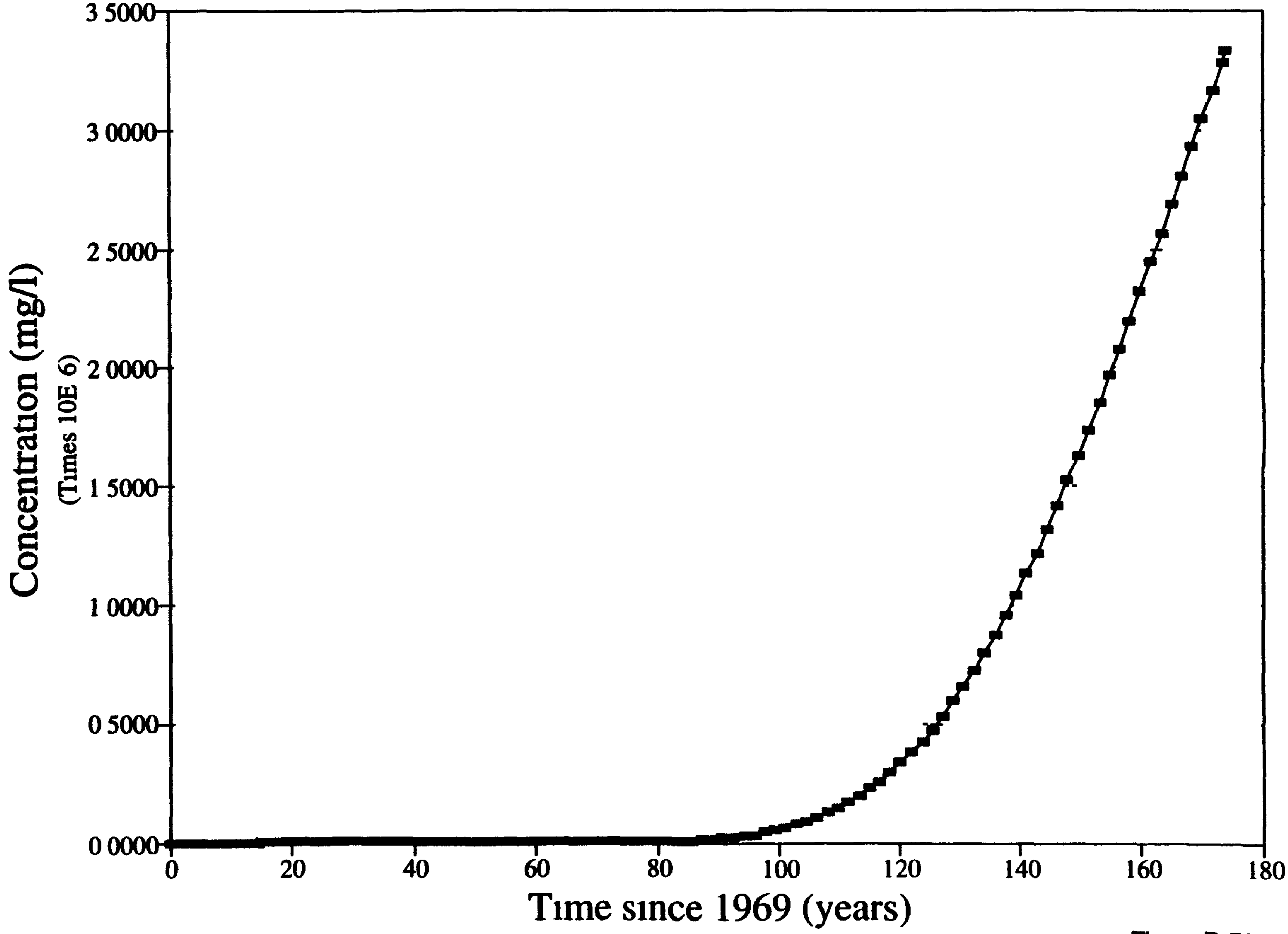



Figure B 52

## Simulated concentration of Selenium down gradient of the French drain

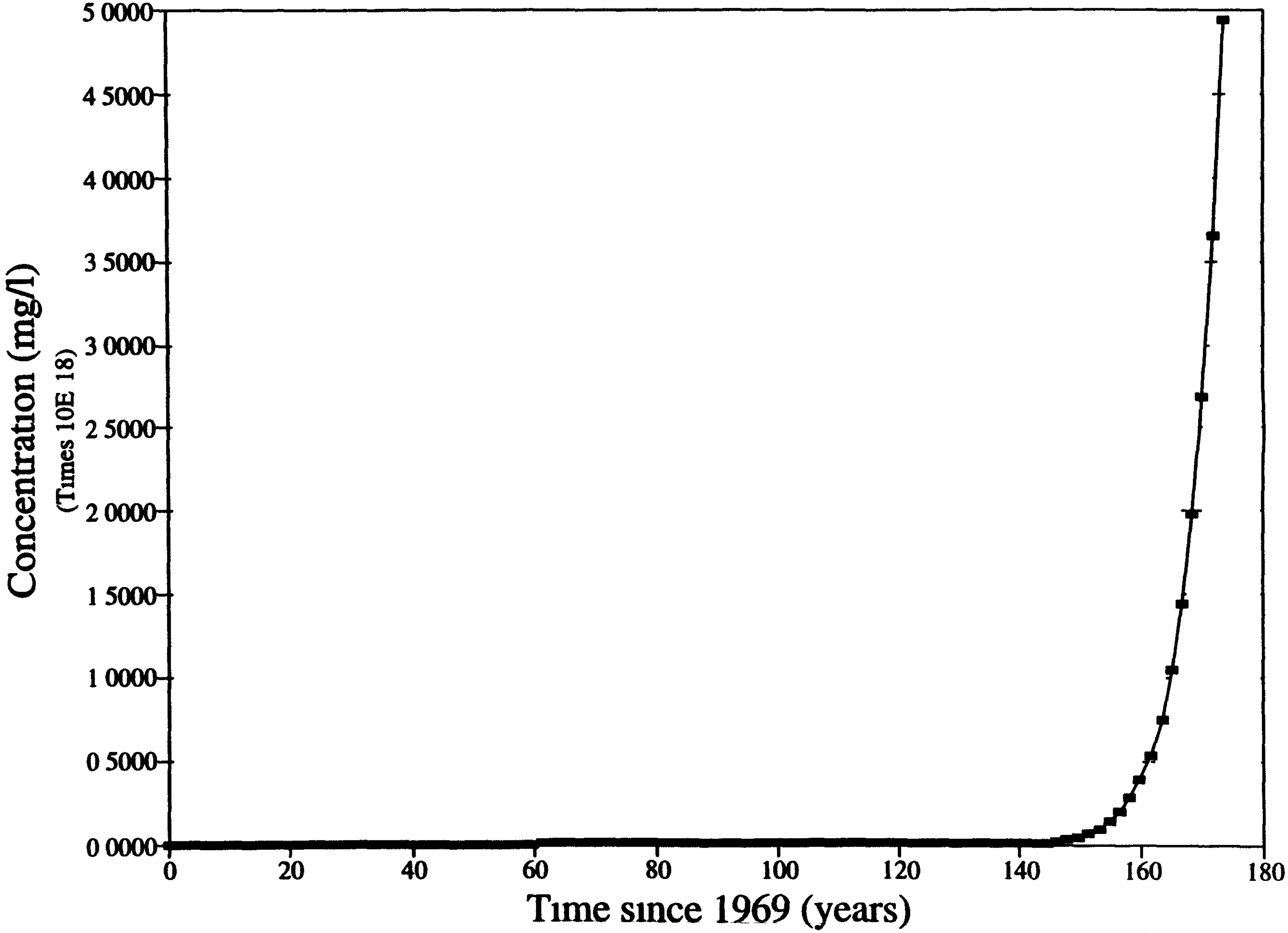
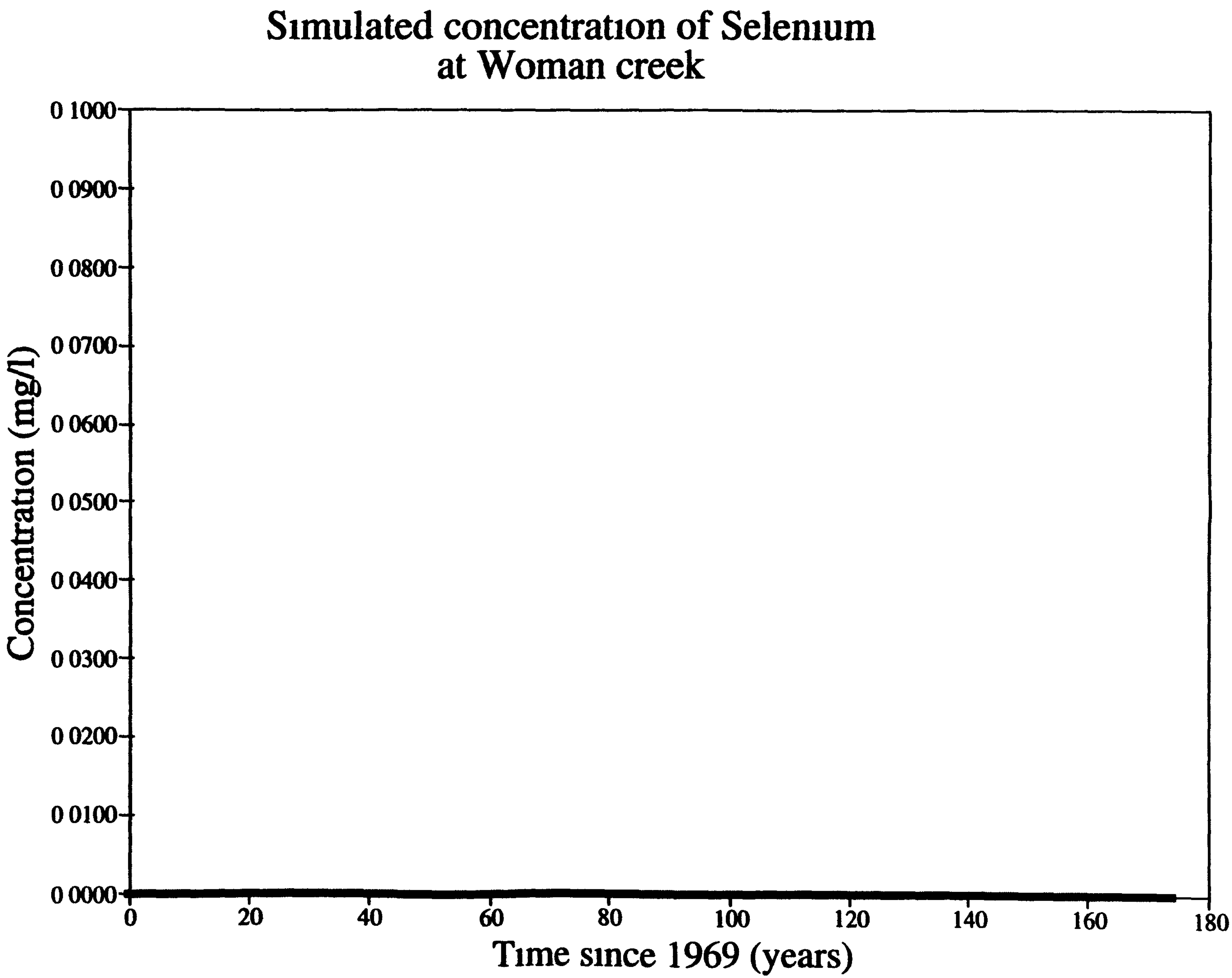



Figure B 53



Simulated concentration of Selenium
at Woman creek
Concentration (mg/l)
0 1000
0 0900
0 0800
0 0700
0 0600
0 0500
0 0400
0 0300
0 0200
0 0100
0 0000
0
20
40
60
80
100
120
140
160
180
Time since 1969 (years)


Figure B 54

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## ACRONYMS

| | |
|---|---|
| 1 1 DCE | 1 1 dichloroethene |
| CERCLA | Comprehensive Environmental Response Compensation and Liability Act |
| $CCL_4$ | carbon tetrachloride |
| CNS | central nervous system |
| DOE | Department of Energy |
| EE | Ecological Evaluation |
| FS | Feasibility Study |
| HI | hazard indices |
| HQ | hazard quotient |
| NOAEL | no observed adverse effect level |
| OU1 | Operable Unit No 1 |
| PCE | tetrachloroethene |
| PHE | Public Health Evaluation |
| RAGS | Risk Assessment Guidance for Superfund |
| RCRA | Resource Conservation and Recovery Act |
| RfD | reference dose |
| RFETS | Rocky Flats Environmental Technology Site |
| RFI/RI | RCRA Facility Investigation/Remedial Investigation |
| SFs | slope factors |
| VOCs | volatile organic compounds |

# C 1 0 INTRODUCTION

The Phase III Resource Conservation and Recovery Act (RCRA) Facility Investigation/Comprehensive Environmental Response Compensation and Liability Act (CERCLA) Remedial Investigation (RFI/RI) at Operable Unit No 1 (OU1) 881 Hillside Area at the Rocky Flats Environmental Technology Site (RFETS) includes a Baseline Risk Assessment (BRA) The BRA is comprised of an Ecological Evaluation (EE) and a Public Health Evaluation (PHE) The results of the complete OU1 PHE are presented in Volume X Appendix F of the Final Phase III RFI/RI dated June 1994 (DOE 1994a)

This risk assessment performed for the OU1 Feasibility Study (FS) is intended to calculate and document the human health risks associated with OU1 assuming that specified remedial actions are incorporated at the site This risk assessment considered the dominating carcinogenic risks noncarcinogenic hazards associated contaminant pathways and receptors determined in the PHE and calculated risk based on contaminant levels at the site due to incorporation of specified remedial actions

## C.2 0 CONTAMINANTS OF CONCERN

The OU1 PHE (DOE 1994a) identified the future onsite adult resident receptor as having the highest potential risk values for the contaminants 1 1-dichloroethene (1 1 DCE) carbon tetrachloride ($CCL_4$) and tetrachloroethene (PCE) These risks were calculated assuming adequate groundwater present and available for receptor use The total risk values in the PHE for 1 1 DCE $CCL_4$ and PCE respectively are 3 8E 2 2 5E 3 and 1 1E 3 with the dominating pathway being ingestion of groundwater for all three contaminants The contaminants with the three highest calculated noncarcinogenic hazard indices (HI) in the PHE for the same receptor assuming use of groundwater are also 1 1 DCE $CCL_4$ and PCE These three contaminants also yielded the highest HIs for the future onsite residential child receptor and are of the same order of magnitude as the adult receptor The three most dominating pathways for these contaminants are ingestion of groundwater, inhalation of volatiles and dermal contact with groundwater These pathways are all driven by groundwater contamination and, therefore this risk calculation focuses on groundwater associated pathways only Groundwater modeling results are used to derive concentrations of contamination in groundwater at woman creek By comparing initial modeling results with respective contaminant specific preliminary remediation goals (PRGs) for Rocky Flats (DOE 1994b) PCE was deemed the most conservative contaminant to use in this risk calculation Detailed groundwater modeling results (refer to Appendix B) for PCE are used to calculate carcinogenic risk and noncarcinogenic HIs

## C 3 0 SCENARIOS AND PATHWAYS

Although onsite residences are not consistent with future land use plans a hypothetical future onsite resident exposure scenario is evaluated in this risk assessment The future onsite resident is assumed to live within the OU1 study area boundary at the woman creek location To use the most conservative scenario for direct ingestion of groundwater one of the future onsite resident scenarios assume that an adequate well water supply exists

A future onsite worker assumed to be an office worker is also quantitatively evaluated in this risk assessment The setting for the office worker is likely to have extensive paved areas and well maintained landscaping It is assumed that municipal water would be supplied to the office building and therefore the future office worker will not directly access OU1 groundwater

### C 3 1 Exposure Pathways

This section discusses the potential release and transport of chemicals from OU1 and identifies exposure pathways by which the future onsite resident or future onsite office worker may potentially be exposed to site contaminants

An exposure pathway describes a specific environmental pathway that can expose an individual to contaminants that are onsite or originate from a site An exposure pathway includes five elements that must be present for an exposure pathway to be complete

- Source of Chemicals
- Mechanism of Chemical Release
- Environmental Transport Medium
- Exposure Point
- Human Intake Route

An incomplete pathway means that no human exposure can occur An exposure pathway is considered to be potentially complete and relevant if there are potential chemical release and transport mechanisms and receptors identified for that exposure pathway

An exposure route is the pathway through which a contaminant enters or impacts an organism There are four basic human exposure routes

- dermal absorption through contact with soil surface water or groundwater
- inhalation of volatile organic compounds (VOCs) or airborne particulates
- ingestion of soil surface water or groundwater
- external irradiation if radionuclides are present

Chemicals that volatilize from groundwater and/or site soils and are released to indoor air also represent a potentially complete inhalation pathway for the future onsite resident and office worker

As documented in the PHE the pathways that dominated the human health risk are associated with groundwater contamination Therefore the pathways considered in this risk assessment will only consider groundwater contamination associated with the potential remedial actions The following paragraphs describe the potential exposure pathways

Receptors that were quantitatively evaluated in the PHE were

- current offsite residents,
- future onsite residents,
- current onsite workers
- future onsite workers and
- future onsite ecological researcher

Of these potential receptors only the future onsite residents and the future onsite workers could be significantly exposed to contaminants in the groundwater Future onsite residents could be exposed to direct ingestion of groundwater dermal contact with groundwater and inhalation of volatiles that have diffused through the house foundation and from indoor use of groundwater such as showering Future onsite workers could be exposed to volatiles that have diffused through the office building foundation Since groundwater will not be used in an office building no direct exposure to groundwater is anticipated for the future onsite worker These two receptors and potential scenarios are considered conservative since neither receptor could be exposed until the RFETS has been released for unrestricted use The remaining receptors evaluated in the PHE do not have significant exposure to groundwater and therefore were not evaluated in this risk assessment

C 3 1 1 Future Onsite Resident

Contaminants that volatilize from site groundwater and are released to indoor air through the house foundation represent a potentially complete inhalation pathway to future onsite residents Assuming that site groundwater is used within the household inhalation of VOCs from indoor water use represents another potentially complete inhalation pathway Inhalation of outdoor VOCs is considered insignificant due to expected dispersal and dilution of the VOCs

Assuming that site groundwater will be used within the future onsite residential household direct ingestion of groundwater contamination represents a potentially complete pathway Future onsite residents also could physically contact contaminated groundwater Therefore dermal absorption of contaminants from contact with contaminated groundwater represents a potentially complete pathway

The location of the groundwater contamination for the future onsite resident is assumed to be woman creek

C 3 1 2 Future Onsite Office Worker

Since the direct use of groundwater is not considered credible for this receptor the only remaining exposure pathway is volatization of contaminants from site groundwater and release to indoor air through the office building foundation The inhalation pathway is then potentially complete for the future onsite office worker Similar to the future onsite resident scenario the inhalation of outdoor VOCs is considered incomplete due to expected dispersal and dilution of the VOCs As with the future onsite resident the location of the contamination for the future onsite office worker is assumed to be woman creek

## C 4 0 EXPOSURE ASSESSMENT AND INTAKE EQUATIONS

Pathway specific exposures or intakes are quantified through the use of intake equations exposure parameters and exposure concentrations Intake equations are pathway specific while exposure parameters and exposure concentrations are scenario-specific and pathway specific Exposure concentrations for this risk assessment have been modeled using groundwater modeling techniques The generalized intake equations associated with each pathway and the non chemical specific parameters that are used in the equations are presented in this section

### C 4 1 Ingestion of Water

Equation 1 was used to calculate direct ingestion or intake of contaminated water The ingestion rate was adjusted in accordance with the scenario

$$\text{Intake (mg/kg/day)} = \frac{CW \times IR \times EF \times ED}{BW \times AT} \qquad (1)$$

where

| | | |
|---|---|---|
| CW | = | Chemical concentration in water (mg/liter) |
| IR | = | Ingestion rate (liter/day) |
| EF | = | Exposure frequency (days/year) |
| ED | = | Exposure duration (years) |
| BW | = | Body weight (kg) |
| AT | = | Averaging time (period over which exposure is averaged in days) |

The chemical concentration in water is a modeled value and the modeling techniques are described in the PHE (DOE 1994a) Some parameters vary between adult and child receptors such as ingestion rates exposure durations and body weights The adult and child ingestion rates are 2 liters and 1 liter per day respectively Exposure frequency for residential receptors is 350 days/year The exposure durations for adult and child receptors are 24 and 6 years respectively The adult and child body weights are 70 kilograms and 15 kilograms, respectively The averaging time for a carcinogen is 25 550 days or 70 years

C 4 2 Dermal Contact With Water

Equation 2 was used to calculate absorbed dose through the skin or intake for the future onsite resident This is the only receptor that potentially can contact contaminated groundwater This equation calculates the actual absorbed dose not the amount of chemical that comes in contact with the skin

$$\text{Absorbed Dose (mg/kg/day)} = \frac{CW \times SA \times PC \times ET \times EF \times ED \times CF}{BW \times AT} \tag{2}$$

where

| | | |
|---|---|---|
| CW | = | Chemical concentration in water (mg/liter) |
| SA | = | Skin surface area available for contact ($cm^2$) |
| PC | = | Chemical specific dermal permeability constant (cm/hr) |
| ET | = | Exposure time (hours/day) |
| EF | = | Exposure frequency (days/year) |
| ED | = | Exposure duration (years) |
| CF | = | Volumetric conversion factor for water (1 liter/1000 $cm^3$) |
| BW | = | Body weight (kg) |
| AT | = | Averaging time (period over which exposure is averaged in days) |

The chemical concentration in water is a modeled value as described in the PHE Some parameters vary between adult and child receptors such as skin surface areas exposure durations, and body weights The adult and child skin surface areas are 23 200 $cm^2$ and 9 180 $cm^2$ respectively The dermal permeability constants are chemical specific and their origination is discussed in the PHE Adult and child exposure times for dermal contact with groundwater are 0 2 hours/day Exposure frequency for a residential adult and child is 350 days/year Adult and child exposure durations are 24 years and 6 years respectively The volumetric conversion factor for water is 0 001 liters/$cm^3$ Adult and child body weights are 70 kilograms and 15 kilograms respectively The averaging time for a carcinogen is 25 550 days or 70 years

## C 4 3 Inhalation of Airborne Contaminants

Exposure scenarios involving the residential adult residential child and office worker include intake of airborne contaminants The contaminants are in the vapor phase and originate from groundwater contaminants volatilizing and diffusing through either a home foundation or office building foundation as applicable Assuming well water is used within the home the residential receptor can also inhale contaminants volatilized during in home water use Dermal absorption of vapor phase contaminants is considered to be a negligible portion of inhalation intakes and therefore is disregarded in accordance with Risk Assessment Guidance for Superfund (RAGS) (EPA 1991) Equation 3 was used to calculate inhalation intakes for residential and office worker receptors

$$\text{Intake (mg/kg/day)} = \frac{CA \times IR \times EF \times ED}{BW \times AT} \tag{3}$$

where

| | | |
|---|---|---|
| CA | = | Contaminant concentration in air ($mg/m^3$) |
| IR | = | Inhalation rate ($m^3$/day) |
| EF | = | Exposure frequency (days/year) |
| ED | = | Exposure duration (years) |
| BW | = | Body weight (kg) |
| AT | = | Averaging time (period over which exposure is averaged in days) |

Both residential and office worker receptors have the potential to inhale volatilized contamination that has diffused through the foundation of either a home or an office building, as applicable It is assumed that groundwater would not service onsite office buildings, therefore only a residential receptor could inhale volatilized contamination due to indoor water use The chemical concentrations in indoor air (volatilized through a foundation and volatilized due to indoor water use) are modeled values as described in the PHE Some parameters vary between the onsite office worker adult and child receptors such as inhalation rates exposure frequencies exposure durations, body weights, and averaging times The inhalation rate is 15 $m^3$/day for a residential adult (assuming indoor activities) and 20 $m^3$/day for both a residential child and office worker The exposure frequency is 350 days/year for a residential adult and child and 250 days/year for an office worker The exposure duration is 24 years for a residential adult 6 years for a residential child and 25 years for an office worker The body weight is 70 kilograms for a residential adult and office worker and 15 kilograms for a residential child

## C 5 0 TOXICITY ASSESSMENT

This section provides the toxicity constants used for risk characterization purposes and summarizes toxicological information Specific derivation of toxicity constants and respective sources is discussed in the PHE For this risk assessment, toxicity information summarized for two categories of potential effects noncarcinogenic and carcinogenic effects These two categories were selected because of the slightly differing methodologies for estimating potential health risks associated with exposures to carcinogens and noncarcinogens

### C 5 1 Tetrachloroethene

Tetrachloroethene also known as perchloroethylene (PCE) has widespread use in the dry cleaning and textile industries It is also used in the cold cleaning and vapor degreasing of metals as a chemical intermediate in the synthesis of fluorocarbons, as a component of aerosol laundry treatment products as a solvent for silicones as the insulating fluid and cooling gas in electrical transformers, and in typewriter correction fluid PCE is not known to occur naturally but contributes to water pollution through leaching from vinyl liners in asbestos-cement water pipelines and as wastewater from metal finishing laundries aluminum-forming organic chemical/plastics manufacturing, and municipal treatment plants Air contamination is the result of emissions and vaporization losses from dry cleaning and industrial metal cleaning (ATSDR 1992)

The effects discussed below are due to occupational exposure levels which are much higher than the expected environmental levels Primarily exposure occurs through inhalation of contaminated air or ingestion of contaminated water PCE can cause lightheadedness dizziness euphoria blindness, cardiac arrhythmias, hypotension, cyanosis respiratory depression, pulmonary hemorrhages, and central nervous system (CNS) depression in acute dosages When chronically dosed, trigeminal nerve impairment liver injury, and chapped skin can occur PCE is metabolized and excreted very slowly Individuals with diseases of the heart, liver, kidneys, and lungs are the most vulnerable to PCE poisoning It has also been known to cause jaundice in newborns from PCE excretion in the breast milk (ATSDR 1992)

Historically few acute or chronic industrial toxicity problems have arisen from the use of this solvent although researchers have reported both hepatotoxity and CNS effects Ingested or inhaled PCE is mostly excreted by the lungs The metabolism of PCE is very slow a very low percentage is excreted in the urine as metabolites Currently no inhalation RfD is available for PCE Oral RfDs have been calculated based on research with rodents Primary effects associated with PCE exposure include liver and kidney damage and CNS depression The oral RfD for chronic exposures is 1E-2 mg/kg/day with an uncertainty factor of 1000 There is medium confidence in this RfD because no one study combined the features required for deriving a high confidence RfD Confidence in the principle study is low because it lacked complete histopathological examination at the no observed adverse effect level (NOAEL) and corroborative studies on its teratogenic and reproductive impacts are lacking (EPA 1994)

PCE is listed as a probable group B2 carcinogen in IRIS has an oral SF of 5 20E-2 and an inhalation SF of 2 03E-3 This classification was based on studies performed on rodents where inhalation produced both leukemia and tumors of the liver PCE is for the most part nonmutagenic and has not been shown to cause reproductive toxicity

Table C 5 1 summarizes chemical specific constants for PCE

## C 5 2 Concentrations of Contamination

Groundwater modeling was used to calculate the expected contamination in groundwater at various locations downgradient of IHSS 119 1 The concentrations were modeled to include the specific remediation scenarios starting in 1969 and continuing in time steps The scenarios that were modeled are no action, continued use of the french drain and extraction well (institutional controls) and remediating the contamination at the source (remediation) The no action scenario was modeled out to the year 2369 (400 years) the continued operation of the french drain and

## Table C 5-1
## Chemical Specific Constants

| | |
|---|---|
| **Chemical** | Tetrachloroethene |
| **Metal or Organic** | Organic |
| **Weight of Evidence** | B2 |
| **SF Ingestion (mg/kg/day)** | 5 20E 2 |
| **SFi Inhalation (mg/kg/day)** | 2 03E 3 |
| **Target System** | Liver/Hepatic Lesions |
| **RfD Ingestion (mg/kg/day)** | 1 0E 2 |
| **RfD Inhalation (mg/kg/day)** | n/a |
| **Dermal Permeability (cm/hr)** | 4 80E-02 |
| **Additional Notes** | RfD Inhalation no data |

extraction well scenario was modeled to year 2269 (300 years) and the remediation scenario was modeled to year 2169 (200 years) The concentrations of PCE at the end of the modeling runs for the no action and continued operation of the french drain and extraction well scenarios were still rising slightly however the peak is expected to occur within a short time frame and at a concentration that is not significantly higher than the last concentration result Therefore the highest concentrations of PCE for these scenarios was conservatively used to calculate carcinogenic risk and noncarcinogenic hazard effects The highest concentration of PCE at woman creek for the remediation scenario occurred during the year 2152 Therefore the concentration for this scenario is assumed to be the 30-year average concentration centered around the year 2152 The calculated groundwater concentrations were then used in the Johnson and Ettinger (1991) soil gas model which considers chemical specific parameters such as Henry s law constant and air diffusion coefficients to calculate a vapor concentration inside a building refer to the PHE for further details To calculate the concentration in indoor air from groundwater use the conservatively modeled groundwater concentrations were multiplied by the volatilization fraction of 0 065 mg/m$^3$ air per mg/l water This conservative approach is consistent with Andelman (1990) and is discussed further in the PHE The concentrations of PCE and associated scenarios are summarized in Table C 5 2

C 5 3 Contaminant Intakes

The intake equations discussed in section 4 0 use the nonchemical specific parameters chemical specific parameters chemical concentrations and appropriate scenarios to calculate respective chemical intakes Tables C 5 3 through C 5 8 summarize the carcinogenic and noncarcinogenic intakes by scenario receptor and pathway

C 5 4 Risk and Hazard Quotient Calculation

Potential carcinogenic risks are expressed as an estimated probability of an individual developing cancer from lifetime exposure to the carcinogen This probability is based on projected intakes and chemical specific dose-response data called cancer slope factors (SFs) Cancer SFs and the

## Table C 5-2
## PCE Concentrations at Woman Creek

| Scenario | Indoor Air Volatiles Diffusing through the Foundation ($mg/m^3$) | Groundwater (mg/l) | Indoor Air from Groundwater Use ($mg/m^3$) |
|---|---|---|---|
| Unchanged contamination discontinued FD and extraction well operations | 9 69E 10 | 3 60E-03 | 2 34E-04 |
| Unchanged contamination continued FD and extraction well operations | 2 32E 12 | 8 62E-06 | 5 60E-07 |
| Remediated contamination discontinued FD and extraction well operations | 1 57E 10 | 5 84E-04 | 3 80E-05 |

**Table C 5 3**
**Carcinogenic Intakes at Woman Creek, No Action Scenario**
**(mg/kg/day)**

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater |
|---|---|---|---|---|
| Future Onsite Resident with Groundwater | 6 83E 11 | 3 38E-05 | 3 77E-06 | 1 65E-05 |
| Future Onsite Resident without Groundwater | 6 83E 11 | N/A | N/A | N/A |
| Future Onsite Office Worker without Groundwater | 6 77E 11 | N/A | N/A | N/A |

**Table C 5-4**
**Carcinogenic Intakes at Woman Creek, French Drain and Extraction Well Scenario**
**(mg/kg/day)**

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater |
|---|---|---|---|---|
| Future Onsite Resident with Groundwater | 1 63E 13 | 8 10E-08 | 9 02E-09 | 3 95E-08 |
| Future Onsite Resident without Groundwater | 1 63E 13 | N/A | N/A | N/A |
| Future Onsite Office Worker without Groundwater | 1 62E 13 | N/A | N/A | N/A |

## Table C 5 5
## Carcinogenic Intakes at Woman Creek, Source Remediation Scenario
## (mg/kg/day)

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater |
|---|---|---|---|---|
| Future Onsite Resident with Groundwater | 1 11E 11 | 5 49E-06 | 6 11E-07 | 2 67E-06 |
| Future Onsite Resident without Groundwater | 1 11E 11 | N/A | N/A | N/A |
| Future Onsite Office Worker without Groundwater | 1 10E 11 | N/A | N/A | N/A |

**Table C 5 6**
**Noncarcinogenic Intakes at Woman Creek, No Action Scenario**
**(mg/kg/day)**

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater |
|---|---|---|---|---|
| Future Onsite Adult Resident with Groundwater | N/A | 9 86E-05 | 1 10E-05 | N/A |
| Future Onsite Child Resident with Groundwater | N/A | 2 30E-04 | 2 03E-05 | N/A |
| Future Onsite Adult Resident without Groundwater | 1 99E 10 | N/A | N/A | N/A |
| Future Onsite Child Resident without Groundwater | 1 24E-09 | N/A | N/A | N/A |
| Future Onsite Office Worker without Groundwater | 1 90E 10 | N/A | N/A | N/A |

## Table C 5-7
## Noncarcinogenic Intakes at Woman Creek, French Drain and Extraction Well Scenario
## (mg/kg/day)

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater |
|---|---|---|---|---|
| Future Onsite Adult Resident with Groundwater | N/A | 2 36E-07 | 2 63E-08 | N/A |
| Future Onsite Child Resident with Groundwater | N/A | 5 51E-07 | 4 86E-08 | N/A |
| Future Onsite Adult Resident without Groundwater | 4 77E 13 | N/A | N/A | N/A |
| Future Onsite Child Resident without Groundwater | 2 97E 12 | N/A | N/A | N/A |
| Future Onsite Office Worker without Groundwater | 4 54E 13 | N/A | N/A | N/A |

## Table C 5 8
## Noncarcinogenic Intakes at Woman Creek, Source Remediation Scenario (mg/kg/day)

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater |
|---|---|---|---|---|
| Future Onsite Adult Resident with Groundwater | N/A | 1 60E-05 | 1 78E-06 | N/A |
| Future Onsite Child Resident with Groundwater | N/A | 3 73E-05 | 3 29E-06 | N/A |
| Future Onsite Adult Resident without Groundwater | 3 23E 11 | N/A | N/A | N/A |
| Future Onsite Child Resident without Groundwater | 2 01E 10 | N/A | N/A | N/A |
| Future Onsite Office Worker without Groundwater | 3 07E 11 | N/A | N/A | N/A |

estimated daily intake of a compound averaged over a lifetime of exposure is used to estimate the incremental risk that an individual exposed to that compound may develop cancer Potential carcinogenic risks are estimated from the following equation

$$\text{Risk} = \text{Intake} \times \text{SF} \qquad (4)$$

where

| | | |
|---|---|---|
| Risk | = | Potential lifetime excess cancer risk (unitless) |
| SF | = | Slope factor for chemicals (mg/kg/day) [1] |
| Intake | = | Chemical intake (mg/kg/day) |

Potential health effects of chronic exposure to noncarcinogenic compounds is assessed by calculating a hazard quotient (HQ) which is derived by dividing the estimated daily intake by a chemical specific RfD as shown in the following equation

$$\text{HQ} = \text{Intake}/\text{RfD} \qquad (5)$$

where

| | | |
|---|---|---|
| HQ | = | Noncancer hazard quotient (unitless) |
| Intake | = | Chemical intake (mg/kg/day) |
| RfD | = | Reference dose (mg/kg/day) |

A HQ greater than 1 0 indicates that exposure to that contaminant, (at the concentrations and for the duration and frequencies of exposure estimated in the exposure assessment) may cause adverse health effects in exposed populations However the level of concern associated with exposure to noncarcinogenic compounds does not increase linearly as HQ values exceed 1 0 In other words HQ values do not represent a probability or a percentage For example, an HQ of 10 does not indicate that adverse health effects are 10 times more likely to occur than an HQ value of 1 0 but that potential adverse health effects are of greater concern

## C 6 0 RISK CHARACTERIZATION

Risk characterization involves estimating the magnitude of potential adverse effects summarizing the nature of the threats to public health and considering the nature and weight of evidence supporting these risk estimates and the degree of uncertainty surrounding the estimates Specifically risk characterization involves combining the results of the exposure and toxicity assessments to provide numerical estimates of health risk These estimates are comparisons of exposure levels with appropriate RfDs or estimates of the lifetime cancer risk with a given intake

Generally to quantify the health risks the intakes are first calculated as identified in section 4 0 for each applicable scenario The intakes were calculated from the concentrations discussed in section 5 2 and the methodology documented in the EPA RAGS (1989) The specific intakes calculated in section 5 3 were then compared to the applicable chemical specific toxicological data presented in section 5 1 to determine the health risk

The health risks from PCE were calculated to determine potential carcinogenic and noncarcinogenic effects as discussed in Sections 6 1 and 6 2 respectively

### C 6 1 Carcinogenic Effects

Carcinogenic risks from exposure to PCE were calculated for a future onsite resident using groundwater, using public water, and for a future onsite office worker using public water The source of contamination considered (1) maintaining the current groundwater contamination level and removing the french drain and extraction well (2) maintaining the current groundwater contamination level and continuing the french drain and extraction well operations and (3) remediating the contamination source and removing the french drain and extraction well These receptors and scenarios considered PCE contamination at woman creek Tables C 6-1 through C 6-3 summarize the results of the risk calculations by scenario receptor and pathway

The three highest carcinogenic risks at woman creek are associated with the future onsite resident using groundwater for household use The risks for the future onsite resident without groundwater and the future office worker without groundwater are negligible (in the $10^{13}$ to $10^{16}$ range)

The scenario that yielded the maximum calculated carcinogenic risk assumed current PCE groundwater contamination and removal of the french drain and extraction well (no action scenario) The total calculated risk for the future onsite resident with this exposure is 1 99E-06 with the dominating pathway of ingestion of groundwater with a risk of 1 76E-06 (see Table C 6-1)

The next highest calculated carcinogenic risk assumed remediation of the contamination and discontinuing the operation of the french drain and extraction well The total calculated risk for the future on site resident with this exposure is 3 22E-07 with the dominating pathway of ingestion of groundwater with a risk of 2 85E-07 (see Table C 6-3)

The third highest calculated carcinogenic risk assumed current PCE groundwater contamination and continued operation of the french drain and the extraction well (Institutional controls) The total calculated risk for the future on site resident with this exposure is 4 76E-09 with the dominating pathway of ingestion of groundwater with a risk of 4 21E-09 (see Table C 6-2)

### C 6 2 Noncarcinogenic Effects

The receptors and pathways used to evaluate carcinogenic effects were also used to evaluate noncarcinogenic effects The hazard indices for PCE are the summed HQs for each exposure pathway If the hazard index exceeds unity there may be a concern for potential health effects and the exposure should be evaluated more closely Tables C 6-4 through C 6-6 summarize the results of the HQ and hazard indices calculations by scenario receptor and pathway

## Table C 6-1
## Carcinogenic Risk at Woman Creek, No Action Scenario

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater | TOTAL |
|---|---|---|---|---|---|
| Future On site Resident with Groundwater | 1 39E 13 | 1 76E-06 | 1 96E-07 | 3 35E-08 | 1 99E-06 |
| Future On site Resident without Groundwater | 1 39E 13 | N/A | N/A | N/A | 1 39E 13 |
| Future On site Office Worker without Groundwater | 1 37E 13 | N/A | N/A | N/A | 1 37E 13 |

## Table C 6-2
## Carcinogenic Risk at Woman Creek, French Drain and Extraction Well Scenario

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater | TOTAL |
|---|---|---|---|---|---|
| Future On site Resident with Groundwater | 3 32E 16 | 4 21E-09 | 4 69E 10 | 8 01E 11 | 4 76E-09 |
| Future On site Resident without Groundwater | 3 32E 16 | N/A | N/A | N/A | 3 32E 16 |
| Future On site Office Worker without Groundwater | 3 29E 16 | N/A | N/A | N/A | 3 29E 16 |

**Table C 6-3**
**Carcinogenic Risk at Woman Creek, Source Remediation Scenario**

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater | TOTAL |
|---|---|---|---|---|---|
| Future On site Resident with Groundwater | 2 25E 14 | 2 85E-07 | 3 18E-08 | 5 43E-09 | 3 22E-07 |
| Future On site Resident without Groundwater | 2 25E 14 | N/A | N/A | N/A | 2 25E 14 |
| Future On site Office Worker without Groundwater | 2 23E 14 | N/A | N/A | N/A | 2 23E 14 |

**Table C 6-4**
**Noncarcinogenic Hazard Indices at Woman Creek, No Action Scenario**

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater | TOTAL |
|---|---|---|---|---|---|
| Future On site Adult Resident with Groundwater | N/A | 9 86E-03 | 1 10E-03 | N/A | 1 10E-02 |
| Future On site Child Resident with Groundwater | N/A | 2 30E-02 | 2 03E-03 | N/A | 2 50E-02 |
| Future On site Adult Resident without Groundwater | N/A | N/A | N/A | N/A | N/A |
| Future On site Child Resident without Groundwater | N/A | N/A | N/A | N/A | N/A |
| Future On site Office Worker without Groundwater | N/A | N/A | N/A | N/A | N/A |

**Table C 6-5**
**Noncarcinogenic Hazard Indices at Woman Creek, French Drain and Extraction Well Scenario**

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater | TOTAL |
|---|---|---|---|---|---|
| Future On site Adult Resident with Groundwater | N/A | 2 36E-05 | 2 63E-06 | N/A | 2 62E-05 |
| Future On site Child Resident with Groundwater | N/A | 5 51E-05 | 4 86E-06 | N/A | 6 00E-05 |
| Future On site Adult Resident without Groundwater | N/A | N/A | N/A | N/A | N/A |
| Future On site Child Resident without Groundwater | N/A | N/A | N/A | N/A | N/A |
| Future On site Office Worker without Groundwater | N/A | N/A | N/A | N/A | N/A |

**Table C 6-6**
**Noncarcinogenic Hazard Indices at Women Creek, Source Remediation Scenario**

| Receptor | Inhalation of Volatiles Diffusing through Foundation | Ingestion of Groundwater | Dermal Contact with Groundwater | Inhalation of Volatiles from Indoor use of Groundwater | TOTAL |
|---|---|---|---|---|---|
| Future On site Adult Resident with Groundwater | N/A | 1 60E-03 | 1 78E-04 | N/A | 1 78E-03 |
| Future On site Child Resident with Groundwater | N/A | 3 73E-03 | 3 29E-04 | N/A | 4 06E-03 |
| Future On site Adult Resident without Groundwater | N/A | N/A | N/A | N/A | N/A |
| Future On site Child Resident without Groundwater | N/A | N/A | N/A | N/A | N/A |
| Future On site Office Worker without Groundwater | N/A | N/A | N/A | N/A | N/A |

The calculation of HQs and respective hazard indices did not yield a significant noncarcinogenic hazard (i e did not approach unity) The highest hazard index is 2 50E-02 for a future onsite child resident with groundwater assuming PCE contamination and discontinuing the french drain and extraction well operations (no action scenario) (see Table C 6-4) The dominating pathway for this receptor is ingestion of groundwater with a HQ of 2 30E-02 The remaining hazard indices ranged from 1 10E-02 to 2 62E-05 HQs were not calculated for receptors that do not have access to groundwater because the only applicable pathway for these receptors is inhalation of volatiles diffusing through the foundation and the PCE inhalation RfD is not available

## C 7 0 SUMMARY

These residual risk calculations discussed in this risk assessment were intended to develop a quantitative assessment of the risk associated with appropriate receptors and scenarios after specific remedial action alternatives have been implemented  Based on information from the PHE the most conservative contamination scenarios receptors and pathways were evaluated Concentrations of contaminants were modeled using groundwater modeling techniques and then receptor intakes were calculated  The intakes were combined with toxicological data in risk and HQ equations to calculate potential probabilities for carcinogenic risk and noncarcinogenic HQs The carcinogenic risks and hazard quotients were then summed by scenario to yield total potential carcinogenic and noncarcinogenic effects

The maximum calculated carcinogenic risk is for the no action scenario  The total risk to the future onsite resident with groundwater is 1 99E-06

The hazard indices calculated for the scenarios and receptors were not significant (i e  did not approach unity)  The maximum hazard index is 2 50E-02 for a future onsite child resident with groundwater assuming the current levels of PCE contamination, and discontinuing operations of the french drain and extraction well

## C 8 0 REFERENCES


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# APPENDIX D

# POTENTIAL APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

## Table E-1 Alternative 0· No Action

| Activity | Resource Description | Qty. | Unit | Bare Costs Per Unit: Mat'l | Bare Costs Per Unit: Equip. | Bare Costs Per Unit: Labor | Bare Costs Per Unit: Sub-contract | Source | Bare Costs: Mat'l | Bare Costs: Equip. | Bare Costs: Labor | Bare Costs: Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Direct Capital Costs** | | | | | | | | | | | | | |
| Decommission French Drain | Backhoe | 1 | day | | $2,200.00 | $362.00 | | Means Ref. | $0 | $2,200 | $362 | $0 | $2,562 |
| Drill Monitoring Wells | Drill & Case 4 wells, 6"diam. & 20'depth | 4 | ea | | | | $25,000.00 | Vender Quote | $0 | $0 | $0 | $100,000 | $100,000 |
| Field Personnel | Surveyor | | | | | | | | | | | | |
| | Health & Safety | 8 | hr | | | $50.00 | | Prof. Judgement | $0 | $0 | $400 | $0 | $400 |
| | Geologist | 8 | hr | | | $65.00 | | Prof. Judgement | $0 | $0 | $520 | $0 | $520 |
| | | 40 | hr | | | $55.00 | | Prof. Judgement | $0 | $0 | $2,200 | $0 | $2,200 |
| **Subtotal Direct Capital Costs** | | | | | | | | | $0 | $2,200 | $3,482 | $100,000 | $105,682 |
| **Indirect Capital Costs** | | | | | | | | | | | | | |
| Misc Labor & Materials | 10% of direct labor & $1.50 in materials cost for each direct labor hour | | | | | | | Facil. Eng. 009 | $84 | $0 | $348 | $0 | $432 |
| Permits | 5% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $0 | $110 | $174 | $0 | $284 |
| Construction Management | 10% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $0 | $220 | $348 | $0 | $568 |
| Project Management | 10% of direct materials, equipment, & labor | | | | | | | EG&G Cost Est. | $0 | $220 | $348 | $0 | $568 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor | | | | | | | Facil. Eng. 009 | $0 | $557 | $881 | $0 | $1,438 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $10,000 | $10,000 |
| **Subtotal Indirect Capital Costs** | | | | | | | | | $84 | $1 107 | $2 100 | $10 000 | $13 290 |
| **Contingency** | 30% of direct and indirect capital costs | | | | | | | Facil. Eng. 009 | $25 | $992 | $1 674 | $33 000 | $35 692 |
| **Total Capital Costs** | | | | | | | | | $109 | $4,299 | $7 256 | $143 000 | $154 664 |
| **Annual O&M Direct Costs** | | | | | | | | | | | | | |
| **Subtotal O&M Direct Costs** | | | | | | | | | $0 | $0 | $0 | $0 | $0 |
| **Total O&M Costs** | | | | | | | | | $0 | $0 | $0 | $0 | $0 |
| **Annual Post Closure Direct Costs** | | | | | | | | | | | | | |
| Semiannual Sampling | Collect Groundwater Samples | 12 | ea | | | | $1,500.00 | Prof. Judgement | $0 | $0 | $0 | $18,000 | $18,000 |
| Analytical Work | Sample Analysis for VOCs & Inorganics | 14 | ea | | | | $4,100 00 | Vender Quote | $0 | $0 | $0 | $57,400 | $57,400 |
| **Subtotal Post Closure Direct Costs** | | | | | | | | | $0 | $0 | $0 | $75,400 | $75,400 |
| **Annual Post Closure Indirect Costs** | | | | | | | | | | | | | |
| Project Management | 10% of post closure direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $0 | $0 | $0 | $0 | $0 |
| Subcontractor Fee | 10% of post closure subcontractor costs | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $7,540 | $7,540 |
| **Subtotal Post Closure Indirect Costs** | | | | | | | | | $0 | $0 | $0 | $7 540 | $7,540 |
| **Contingency** | 30% of total post closure direct and indirect costs | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $24,882 | $24,882 |
| **Total Annual Post Closure Costs** | | | | | | | | | $0 | $0 | $0 | $107,822 | $107 822 |
| **Total Post Closure Costs (30 yrs @ 5% discount rate)** | | | | | | | | | $0 | $0 | $0 | $1,740,363 | $1,740,363 |
| **Total Cost Of Alternative** | | | | | | | | | $109 | $4,299 | $7,256 | $1 883 363 | $1 895 027 |

## Table E-2 Alternative 1 Institutional Controls Without the French Drain

| Activity | Resource Description | Qty. | Unit | Bare Costs Per Unit: Mat'l | Bare Costs Per Unit: Equip. | Bare Costs Per Unit: Labor | Bare Costs Per Unit: Sub-contract | Source | Bare Costs: Mat'l | Bare Costs: Equip. | Bare Costs: Labor | Bare Costs: Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Direct Capital Costs** | | | | | | | | | | | | | |
| Decommission French Drain | Backhoe | 1 | day | | $2,200.00 | $362.00 | | Means Ref. | $0 | $2,200 | $362 | $0 | $2,562 |
| Drill Monitoring Wells | Drill & Case 4 wells, 6"diam. & 20'depth | 4 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $100,000 | $100,000 |
| Field Personnel | Surveyor | 8 | hr | | | $50.00 | | Pref. Judgement | $0 | $0 | $400 | $0 | $400 |
| | Health & Safety | 8 | hr | | | $65.00 | | Pref. Judgement | $0 | $0 | $520 | $0 | $520 |
| | Geologist | 40 | hr | | | $55.00 | | Pref. Judgement | $0 | $0 | $2,200 | $0 | $2,200 |
| **Subtotal Direct Capital Costs** | | | | | | | | | $0 | $2,200 | $3,482 | $100,000 | $105,682 |
| **Indirect Capital Costs** | | | | | | | | | | | | | |
| Misc. Labor & Materials | 10% of direct labor & $1.50 in materials cost for each direct labor hour | | | | | | | Facil. Eng. 000 | $84 | $0 | $348 | $0 | $432 |
| Permits | 5% of direct materials, equipment, & labor | | | | | | | Pref. Judgement | $0 | $110 | $174 | $0 | $284 |
| Construction Management | 10% of direct materials, equipment, & labor | | | | | | | Pref. Judgement | $0 | $220 | $348 | $0 | $568 |
| Project Management | 10% of direct materials, equipment, & labor | | | | | | | EG&G Cost Est. | $0 | $220 | $348 | $0 | $568 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor | | | | | | | Facil. Eng. 000 | $0 | $557 | $881 | $0 | $1,438 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $10,000 | $10,000 |
| **Subtotal Indirect Capital Costs** | | | | | | | | | $84 | $1,107 | $2,100 | $10,000 | $13,290 |
| **Contingency** | 30% of direct and indirect capital costs | | | | | | | Facil. Eng. 000 | $25 | $992 | $1,674 | $33,000 | $35,692 |
| **Total Capital Costs** | | | | | | | | | $109 | $4,299 | $7,256 | $143,000 | $154,664 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual O&M Direct Costs** | | | | | | | | | | | | | |
| **Subtotal O&M Direct Costs** | | | | | | | | | $0 | $0 | $0 | $0 | $0 |
| **Total O&M Costs** | | | | | | | | | $0 | $0 | $0 | $0 | $0 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual Post Closure Direct Costs** | | | | | | | | | | | | | |
| Semiannual Sampling | Groundwater Samples | 12 | ea | | | | $1,500.00 | Pref. Judgement | $0 | $0 | $0 | $18,000 | $18,000 |
| Analytical Work | Sample Analysis for VOCs & Inorganics | 14 | ea | | | | $4,100.00 | Vendor Quote | $0 | $0 | $0 | $57,400 | $57,400 |
| **Subtotal Post Closure Direct Costs** | | | | | | | | | $0 | $0 | $0 | $75,400 | $75,400 |
| **Annual Post Closure Indirect Costs** | | | | | | | | | | | | | |
| Project Management | 10% of post closure direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $0 | $0 | $0 | $0 | $0 |
| Subcontractor Fee | 10% of post closure subcontractor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $7,540 | $7,540 |
| **Subtotal Post Closure Indirect Costs** | | | | | | | | | $0 | $0 | $0 | $7,540 | $7,540 |
| **Contingency** | 30% of total post closure direct and indirect costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $24,882 | $24 882 |
| **Total Annual Post Closure Costs** | | | | | | | | | $0 | $0 | $0 | $107,822 | $107,822 |
| **Total Post Closure Costs (30 yrs @ 5% discount rate)** | | | | | | | | | $0 | $0 | $0 | $1,740,363 | $1,740,363 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Total Cost Of Alternative** | | $109 | $4,299 | $7,256 | $1 883,363 | $1,895 027 |

**Table E-3 Alternative 2 Institutional Controls With the French Drain**

| Activity | Resource Description | Qty. | Unit | Bare Costs Per Unit: Mat'l | Bare Costs Per Unit: Equip. | Bare Costs Per Unit: Labor | Bare Costs Per Unit: Sub-contract | Source | Bare Costs: Mat'l | Bare Costs: Equip. | Bare Costs: Labor | Bare Costs: Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Direct Capital Costs** | | | | | | | | | | | | | |
| Drill Monitoring Wells | Drill & Case 4 wells, 6"diam. & 20'depth | 4 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $100,000 | $100,000 |
| | | | | | | | | | | | | | |
| Field Personnel | Surveyor | 8 | hr | | | $50.00 | | Prof. Judgement | $0 | $0 | $400 | $0 | $400 |
| | Health & Safety | 8 | hr | | | $65.00 | | Prof. Judgement | $0 | $0 | $520 | $0 | $520 |
| | Geologist | 40 | hr | | | $55.00 | | Prof. Judgement | $0 | $0 | $2,200 | $0 | $2,200 |
| **Subtotal Direct Capital Costs** | | | | | | | | | $0 | $0 | $3,120 | $100,000 | $103,120 |
| **Indirect Capital Costs** | | | | | | | | | | | | | |
| Misc. Labor & Materials | 10% of direct labor & $1.50 in materials cost for each direct labor hour | | | | | | | Facil. Eng. 009 | $84 | $0 | $312 | $0 | $396 |
| Permits | 5% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $0 | $0 | $156 | $0 | $156 |
| Construction Management | 10% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $0 | $0 | $312 | $0 | $312 |
| Project Management | 10% of direct materials, equipment, & labor | | | | | | | EG&G Cost Est. | $0 | $0 | $312 | $0 | $312 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor | | | | | | | Facil. Eng. 009 | $0 | $0 | $789 | $0 | $789 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $10,000 | $10,000 |
| **Subtotal Indirect Capital Costs** | | | | | | | | | $84 | $0 | $1,881 | $10,000 | $11,965 |
| | | | | | | | | | | | | | |
| **Contingency** | **30% of direct and indirect capital costs** | | | | | | | Facil. Eng. 009 | $25 | $0 | $1,500 | $33,000 | $34,526 |
| | | | | | | | | | | | | | |
| **Total Capital Costs** | | | | | | | | | $109 | $0 | $6,502 | $143,000 | $149 611 |

| Activity | Resource Description | Qty. | Unit | Bare Costs Per Unit: Mat'l | Bare Costs Per Unit: Equip. | Bare Costs Per Unit: Labor | Bare Costs Per Unit: Sub-contract | Source | Bare Costs: Mat'l | Bare Costs: Equip. | Bare Costs: Labor | Bare Costs: Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual O&M Direct Costs** | | | | | | | | | | | | | |
| Groundwater Treatment | UV/Peroxide &IX Treatment System | 1 | yr | | | | $676,000.00 | (1) | $0 | $0 | $0 | $676,000 | $676,000 |
| **Subtotal O&M Direct Costs** | | | | | | | | | $0 | $0 | $0 | $676,000 | $676,000 |
| **Annual O&M Indirect Costs** | | | | | | | | | | | | | |
| Misc Labor & Materials | 10% of direct labor & $1.50 in material cost for each direct labor hour | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $0 | $0 |
| Project Management | 10% of direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $0 | $0 | $0 | $0 | $0 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor costs | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $0 | $0 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $67,600 | $67,600 |
| **Subtotal O&M Indirect Costs** | | | | | | | | | $0 | $0 | $0 | $67,600 | $67,600 |
| | | | | | | | | | | | | | |
| **Contingency** | **30% of total direct and indirect O&M costs** | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $223,080 | $223,080 |
| | | | | | | | | | | | | | |
| **Total Annual O&M Cost** | | | | | | | | | $0 | $0 | $0 | $966,680 | $966,680 |
| | | | | | | | | | | | | | |
| **Total O&M Costs (30 yrs @ 5% discount rate)** | | | | | | | | | $0 | $0 | $0 | $15,605,253 | $15,605,253 |

| Activity | Resource Description | Qty. | Unit | Bare Costs Per Unit: Mat'l | Bare Costs Per Unit: Equip. | Bare Costs Per Unit: Labor | Bare Costs Per Unit: Sub-contract | Source | Bare Costs: Mat'l | Bare Costs: Equip. | Bare Costs: Labor | Bare Costs: Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual Post Closure Direct Costs** | | | | | | | | | | | | | |
| Semiannual Sampling | Collect Groundwater Samples | 12 | ea | | | | $1,500.00 | Prof. Judgement | $0 | $0 | $0 | $18,000 | $18,000 |
| Analytical Work | Sample Analysis for VOCs & Inorganics | 14 | ea | | | | $4,100.00 | Vendor Quote | $0 | $0 | $0 | $57,400 | $57,400 |
| **Subtotal Post Closure Direct Costs** | | | | | | | | | $0 | $0 | $0 | $75,400 | $75,400 |
| **Annual Post Closure Indirect Costs** | | | | | | | | | | | | | |
| Project Management | 10% of post closure direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $0 | $0 | $0 | $0 | $0 |
| Subcontractor Fee | 10% of post closure subcontractor costs | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $7,540 | $7,540 |
| **Subtotal Post Closure Indirect Costs** | | | | | | | | | $0 | $0 | $0 | $7,540 | $7,540 |
| | | | | | | | | | | | | | |
| **Contingency** | **30% of total post closure direct and indirect costs** | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $24,882 | $24,882 |
| | | | | | | | | | | | | | |
| **Total Annual Post Closure Costs** | | | | | | | | | $0 | $0 | $0 | $107,822 | $107,822 |

| Activity | Resource Description | Qty | Unit | Bare Costs Per Unit | | | | Subtotal | Bare Costs | | | | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Mat'l | Equip. | Labor | Sub-contract | | Mat'l | Equip. | Labor | Sub-contract | |
| Total Post Closure Costs (30 yrs @ 5% discount rate) | | | | | | | | | $0 | $0 | $0 | $1,740,563 | $1,740,563 |
| Total Cost Of Alternative | | | | | | | | | $109 | $0 | $6,502 | $17,486,616 | $17 493,227 |

(1) Costs represent annual operating costs as presented in the Phase I Preliminary Plan For Future Utilization of Existing Water Treatment Facilities At Rocky Flats Plant, Draft Report (June 15 1994)

## Table E-4 Alternative 3 Modified French Drain With Additional Extraction Wells

| Activity | Resource Description | Qty. | Unit | Bare Costs Per Unit: Mat'l | Equip. | Labor | Sub-contract | Source | Bare Costs: Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Direct Capital Costs** | | | | | | | | | | | | | |
| Additional Extraction Wells | Drill 4 Extraction Wells, 6" diam, 20 ft depth | 4 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $100,000 | $100,000 |
| | Sump Pumps | 4 | ea | | $300.00 | | | Vendor Quote | $0 | $1,200 | $0 | $0 | $1,200 |
| | PVC Piping to French Drain Sump, 2.5" | 800 | lf | $1.70 | | $2.19 | | Means Ref. | $1,360 | $0 | $1,752 | $0 | $3,112 |
| Drill Monitoring Wells | Drill & Case 4 wells, 6"diam. & 20'depth | 4 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $100,000 | $100,000 |
| Field Personnel | Surveyor | 16 | hr | | | $50.00 | | Prof. Judgement | $0 | $0 | $800 | $0 | $800 |
| | Health & Safety | 12 | hr | | | $65.00 | | Prof. Judgement | $0 | $0 | $780 | $0 | $780 |
| | Geologist | 60 | hr | | | $55.00 | | Prof. Judgement | $0 | $0 | $3,300 | $0 | $3,300 |
| **Subtotal Direct Capital Costs** | | | | | | | | | $1,360 | $1,200 | $6,632 | $200,000 | $209,192 |
| **Indirect Capital Costs** | | | | | | | | | | | | | |
| Misc. Labor & Materials | 10% of direct labor & $1.50 in materials cost for each direct labor hour | | | | | | | Facil. Eng. 000 | $132 | $0 | $663 | $0 | $795 |
| Permits | 5% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $68 | $60 | $332 | $0 | $460 |
| Construction Management | 10% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $136 | $120 | $663 | $0 | $919 |
| Project Management | 10% of direct materials, equipment, & labor | | | | | | | EG&G Cost Est. | $136 | $120 | $663 | $0 | $919 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor | | | | | | | Facil. Eng. 000 | $344 | $304 | $1,678 | $0 | $2,326 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $20,000 | $20,000 |
| **Subtotal Indirect Capital Costs** | | | | | | | | | $816 | $604 | $3 999 | $20,000 | $25,419 |
| **Contingency** | 30% of direct and indirect capital costs | | | | | | | Facil. Eng. 000 | $653 | $541 | $3,189 | $66,000 | $70,383 |
| **Total Capital Costs** | | | | | | | | | $2,829 | $2,345 | $13,820 | $286,000 | $304,994 |

| Activity | Resource Description | Qty. | Unit | Mat'l | Equip. | Labor | Sub-contract | Source | Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual O&M Direct Costs** | | | | | | | | | | | | | |
| Groundwater Treatment | UV/Peroxide &IX Treatment System | 1 | yr | | | | $676,000.00 | (1) | $0 | $0 | $0 | $676,000 | $676,000 |
| **Subtotal O&M Direct Costs** | | | | | | | | | $0 | $0 | $0 | $676,000 | $676,000 |
| **Annual O&M Indirect Costs** | | | | | | | | | | | | | |
| Misc. Labor & Materials | 10% of direct labor & $1.50 in material cost for each direct labor hour | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $0 | $0 |
| Project Management | 10% of direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $0 | $0 | $0 | $0 | $0 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $0 | $0 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $67,600 | $67,600 |
| **Subtotal O&M Indirect Costs** | | | | | | | | | $0 | $0 | $0 | $67,600 | $67,600 |
| **Contingency** | 30% of total direct and indirect O&M costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $223,080 | $223,080 |
| **Total Annual O&M Cost** | | | | | | | | | $0 | $0 | $0 | $966,680 | $966,680 |
| **Total O&M Costs (30 yrs @ 5% discount rate)** | | | | | | | | | $0 | $0 | $0 | $15,603,253 | $15,603,253 |

| Activity | Resource Description | Qty. | Unit | Mat'l | Equip. | Labor | Sub-contract | Source | Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual Post Closure Direct Costs** | | | | | | | | | | | | | |
| Semiannual Sampling | Collect Groundwater Samples | 12 | ea | | | | $1,500.00 | Prof. Judgement | $0 | $0 | $0 | $18,000 | $18,000 |
| Analytical Work | Sample Analysis for VOCs & Inorganics | 14 | ea | | | | $4,100.00 | Vendor Quote | $0 | $0 | $0 | $57,400 | $57,400 |
| **Subtotal Post Closure Direct Costs** | | | | | | | | | $0 | $0 | $0 | $75,400 | $75,400 |
| **Annual Post Closure Indirect Costs** | | | | | | | | | | | | | |
| Project Management | 10% of post closure direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $0 | $0 | $0 | $0 | $0 |
| Subcontractor Fee | 10% of post closure subcontractor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $7,540 | $7,540 |
| **Subtotal Post Closure Indirect Costs** | | | | | | | | | $0 | $0 | $0 | $7,540 | $7,540 |

| Activity | Resource Description | Qty | Unit | Bare Costs Per Unit: Mat'l | Bare Costs Per Unit: Equip. | Bare Costs Per Unit: Labor | Bare Costs Per Unit: Sub-contract | Source | Bare Costs: Mat'l | Bare Costs: Equip. | Bare Costs: Labor | Bare Costs: Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Contingency | 30% of total post closure direct and indirect costs | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $24,882 | $24,882 |
| Total Annual Post Closure Costs | | | | | | | | | $0 | $0 | $0 | $107,822 | $107,822 |
| Total Post Closure Costs (30 yrs @ 5% discount rate) | | | | | | | | | $0 | $0 | $0 | $1 740,365 | $1 740,365 |
| Total Cost Of Alternative | | | | | | | | | $2,829 | $2,845 | $13,820 | $17,629,615 | $17,648,810 |

(1) Costs represent annual operating costs as presented in the Phase I Preliminary Plan For Future Utilization of Existing Water Treatment Facilities At Rocky Flats Plant, Draft Report (June 15 1994)

**Table E-5 Alternative 4 Groundwater Pumping With Soil Vapor Extraction**

| Activity | Resource Description | Qty | Unit | Bare Costs Per Unit: Mat'l | Equip. | Labor | Sub-contract | Source | Bare Costs: Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Direct Capital Costs** | | | | | | | | | | | | | |
| Soil Gas Survey | Geologist | 120 | hr | | | $55.00 | | Prof. Judgement | $0 | $0 | $6,600 | $0 | $6,600 |
| | Field Technician | 80 | hr | | | $35.00 | | Prof. Judgement | $0 | $0 | $2,800 | $0 | $2,800 |
| | Portable GC | 2 | wk | | $1,000.00 | | | Prof. Judgement | $0 | $2,000 | $0 | $0 | $2,000 |
| | Probes, Pump, and Misc. Equipment | 100 | ea | | $15.00 | | | Prof. Judgement | $0 | $1,500 | $0 | $0 | $1,500 |
| Dewatering | Drill Extraction Wells, 6" diam, 20 ft depth | 2 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $50,000 | $50,000 |
| | 10 gpm submersible pumps | 2 | ea | | $300.00 | | | Vendor Quote | $0 | $600 | $0 | $0 | $600 |
| | PVC Piping to French Drain Sump, 2.5" | 400 | lf | $1.70 | | $2.19 | | Means Ref. | $680 | $0 | $876 | $0 | $1,556 |
| SVE System | Drill & Install Casing for Vapor Extraction Wells, 4"diam & 20' depth | 15 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $375,000 | $375,000 |
| | Vapor Extraction System | 2 | ea | | | | $5,280.00 | Vendor Quote | $0 | $0 | $0 | $10,560 | $10,560 |
| | 4" PVC Piping Including Fittings | 300 | lf | $3.41 | | $2.77 | | Means Ref. | $1,023 | $0 | $831 | $0 | $1,854 |
| | 6" PVC | 40 | lf | $5.25 | | $2.81 | | Means Ref. | $210 | $0 | $112 | $0 | $322 |
| | 4" Butterfly Valves, PVC | 3 | ea | $300.00 | | $100.00 | | Vendor Quote | $900 | $0 | $300 | $0 | $1,200 |
| | Manholes | 15 | ea | | | | $1,500.00 | Vendor Quote | $0 | $0 | $0 | $22,500 | $22,500 |
| | Vacuum Gagues | 15 | ea | | | | $150.00 | Vendor Quote | $0 | $0 | $0 | $2,250 | $2,250 |
| | Flow Element/Local Indicator | 3 | ea | | | | $2,000.00 | Vendor Quote | $0 | $0 | $0 | $6,000 | $6,000 |
| | Shed Housing SVE Pumps & Carbon Adsorption Equipment | 320 | sq ft | | | | $25.00 | Prof. Judgement | $0 | $0 | $0 | $8,000 | $8,000 |
| | Electric Heater | 1 | ea | | $350.00 | | | Vendor Quote | $0 | $350 | $0 | $0 | $350 |
| Installation of Equipment | Installation Mechanical & Electrical | 64 | hrs | | | $35.00 | | Prof. Judgement | $0 | $0 | $2,240 | $0 | $2,240 |
| | Materials | 1 | ls | $400.00 | | | | Prof. Judgement | $400 | $0 | $0 | $0 | $400 |
| Off-gas Treatment | Carbon Adsorption System | 2 | ea | | $5,218.00 | | | Vendor Quote | $0 | $10,436 | $0 | $0 | $10,436 |
| | Initial Granular Activated Carbon (3,000 lbs | 1 | ls | $3,240.00 | | | | Vendor Quote | $3,240 | $0 | $0 | $0 | $3,240 |
| Drill Monitoring Wells | Drill & Case 4 wells, 6"diam. & 20'depth | 4 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $100,000 | $100,000 |
| Additional Field Personnel | Surveyor | 40 | hr | | | $50.00 | | Prof. Judgement | $0 | $0 | $2,000 | $0 | $2,000 |
| | Health & Safety | 16 | hr | | | $65.00 | | Prof. Judgement | $0 | $0 | $1,040 | $0 | $1,040 |
| | Geologist | 80 | hr | | | $55.00 | | Prof. Judgement | $0 | $0 | $4,400 | $0 | $4,400 |
| SVE Well Closure (1) | Labor | 120 | hr | | | $35.00 | | Prof. Judgement | $0 | $0 | $3,271 | $0 | $3,271 |
| | Bentonite Grout Wells | 1.40 | CY | $54.00 | | | | Vendor Quote | $59 | $0 | $0 | $0 | $59 |
| Decommission French Drain (1) | Backhoe | 1 | day | | $2,200.00 | $362.00 | | Means Ref. | $0 | $1,713 | $282 | $0 | $1,995 |
| **Subtotal Direct Capital Costs** | | | | | | | | | $6,512 | $16,599 | $24,752 | $574,310 | $622,174 |
| **Indirect Capital Costs** | | | | | | | | | | | | | |
| Eng., Design & Inspection | 15% of direct materials, equipment, & labor | | | | | | | Facil. Eng. 000 | $977 | $2,490 | $3,713 | $0 | $7,180 |
| Misc. Labor & Materials | 10% of direct labor & $1.50 in materials cost for each direct labor hour | | | | | | | Facil. Eng. 000 | $780 | $0 | $2,475 | $0 | $3,255 |
| Permits | 5% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $326 | $830 | $1,238 | $0 | $2,393 |
| Construction Management | 10% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $651 | $1,660 | $2,475 | $0 | $4,786 |
| Project Management | 10% of direct materials, equipment, & labor ED&I | | | | | | | EG&G Cost Est. | $749 | $1,909 | $2,847 | $0 | $5,504 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor | | | | | | | Facil. Eng. 000 | $1,648 | $4,200 | $6,262 | $0 | $12,109 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $57,431 | $57,431 |
| **Subtotal Indirect Capital Costs** | | | | | | | | | $5,130 | $11,088 | $19,010 | $57 431 | $92,659 |
| **Contingency** | 30% of direct and indirect capital costs | | | | | | | Facil. Eng. 000 | $3,493 | $8,306 | $13 129 | $189 522 | $214,450 |
| **Total Capital Costs** | | | | | | | | | $15,134 | $35,994 | $56,891 | $821,263 | $929,282 |

| Activity | Resource Description | Qty | Unit | Bare Costs Per Unit: Mat'l | Equip. | Labor | Sub-contract | Source | Bare Costs: Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual O&M Direct Costs** | | | | | | | | | | | | | |
| Operations | Replacement Granular Activated Carbon | 9,000 | lb | $1.08 | | $1.25 | | Vendor Quote | $9,720 | $0 | $11,250 | $0 | $20,970 |
| | Transportation of Spent GAC | 4 | loads | | | | $2,700.00 | Vendor Quote | $0 | $0 | $0 | $10,800 | $10,800 |
| | Disposal of Granular Activated Carbon | 12,000 | lb | | | | $0.34 | Vendor Quote | $0 | $0 | $0 | $4,080 | $4,080 |
| | Electrical Costs of Vacuum Pumps | 36 | wk | $47.00 | | | | Prof. Judgement | $1,692 | $0 | $0 | $0 | $1,692 |
| | Electrical Costs of Heater | 24 | wks | $23.63 | | | | Prof. Judgement | $567 | $0 | $0 | $0 | $567 |
| | Confirmatory Sampling | 80 | ea | | | | $150.00 | Prof. Judgement | $0 | $0 | $0 | $12,000 | $12,000 |
| | Groundwater Treatment @ IM/IRA Treat. Facil. | 1 | yr | | | | $676,000.00 | (2) | $0 | $0 | $0 | $676,000 | $676,000 |
| | | | | | | | | | | | | | |
| Maintenance | Labor | 192 | hr | | | $35.00 | | Prof. Judgement | $0 | $0 | $6,720 | $0 | $6,720 |
| | Materials & Parts | 12 | mo | $200.00 | | | | Prof. Judgement | $2,400 | $0 | $0 | $0 | $2,400 |
| | | | | | | | | | | | | | |
| Personnel | Operator | 2,080 | hr | | | $35.00 | | Prof. Judgement | $0 | $0 | $72,800 | $0 | $72,800 |
| | H&S | 96 | hr | | | $65.00 | | Prof. Judgement | $0 | $0 | $6,240 | $0 | $6,240 |
| | Geologist | 192 | hr | | | $55.00 | | Prof. Judgement | $0 | $0 | $10,560 | $0 | $10,560 |
| **Subtotal O&M Direct Costs** | | | | | | | | | $14,379 | $0 | $107,570 | $702,880 | $824,829 |
| **Annual O&M Indirect Costs** | | | | | | | | | | | | | |
| Misc. Labor & Materials | 10% of direct labor & $1.50 in material cost for each direct labor hour | | | | | | | Facil. Eng. 000 | $3,840 | $0 | $10,757 | $0 | $14,597 |
| Project Management | 10% of direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $1,438 | $0 | $10,757 | $0 | $12,195 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor costs | | | | | | | Facil. Eng. 000 | $3,636 | $0 | $27,215 | $0 | $30,853 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $70,288 | $70,288 |
| **Subtotal O&M Indirect Costs** | | | | | | | | | $8,916 | $0 | $48,729 | $70,288 | $127,933 |
| | | | | | | | | | | | | | |
| **Contingency** | 30% of total direct and indirect O&M costs | | | | | | | Facil. Eng. 000 | $6,988 | $0 | $46,890 | $231 950 | $285,829 |
| | | | | | | | | | | | | | |
| **Total Annual O&M Cost** | | | | | | | | | $30,283 | $0 | $203,189 | $1,005,118 | $1,238,591 |
| | | | | | | | | | | | | | |
| **Total O&M Costs (expenditures occurs in yrs 2-5 @ 5% discount rate) (3)** | | | | | | | | | $107,363 | $0 | $720,496 | $4,530,780 | $5,358,661 |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual Post Closure Direct Costs** | | | | | | | | | | | | | |
| Semiannual Sampling | Collect Groundwater Samples | 12 | ea | | | | $1,500.00 | Prof. Judgement | $0 | $0 | $0 | $18,000 | $18,000 |
| Analytical Work | Sample Analysis for VOCs & Inorganics | 14 | ea | | | | $4,100.00 | Vendor Quote | $0 | $0 | $0 | $57,400 | $57,400 |
| **Subtotal Post Closure Direct Costs** | | | | | | | | | $0 | $0 | $0 | $75,400 | $75,400 |
| **Annual Post Closure Indirect Costs** | | | | | | | | | | | | | |
| Project Management | 10% of post closure direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $0 | $0 | $0 | $0 | $0 |
| Subcontractor Fee | 10% of post closure subcontractor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $7,540 | $7,540 |
| **Subtotal Post Closure Indirect Costs** | | | | | | | | | $0 | $0 | $0 | $7,540 | $7,540 |
| | | | | | | | | | | | | | |
| **Contingency** | 30% of total post closure direct and indirect costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $24,882 | $24,882 |
| | | | | | | | | | | | | | |
| **Total Annual Post Closure Costs** | | | | | | | | | $0 | $0 | $0 | $107 822 | $107,822 |
| | | | | | | | | | | | | | |
| **Total Post Closure Costs (continues for 30 yrs after completion of remedial action @ 5% discount rate)** | | | | | | | | | $0 | $0 | $0 | $1,853 773 | $1,853,773 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Total Cost Of Alternative** | | $122,517 | $35 994 | $777,389 | $7,205,817 | $8,141 717 |

(1) Future capital cost that takes place upon completion of treatment. (yr 5 @ 5% discount rate total cost is in 1994 dollars)

(2) Costs represent annual operating costs as presented in the Phase I Preliminary Plan For Future Utilization of Existing W ter Treatment Facilities At Rocky Flats Plant, Draft Report (June 15 1994)

(3) Operational expenses for the UV/peroxide water treatment plant during year 1 have also been included in the total cost.

## Table E-6 Alternative 5 Groundwater Pumping and Soil Vapor Extraction With Thermal Enhancement

| Activity | Resource Description | Qty | Unit | Bare Costs Per Unit: Mat'l | Equip. | Labor | Sub-contract | Source | Bare Costs: Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Direct Capital Costs** | | | | | | | | | | | | | |
| Soil Gas Survey | Geologist | 120 | hr | | | $55.00 | | Prof. Judgement | $0 | $0 | $6,600 | $0 | $6,600 |
| | Field Technician | 80 | hr | | | $35.00 | | Prof. Judgement | $0 | $0 | $2,800 | $0 | $2,800 |
| | Portable GC | 2 | wk | | $1,000.00 | | | Prof. Judgement | $0 | $2,000 | $0 | $0 | $2,000 |
| | Probes, Pump, and Misc. Equipment | 100 | ea | | $15.00 | | | Prof. Judgement | $0 | $1,500 | $0 | $0 | $1,500 |
| | | | | | | | | | | | | | |
| Dewatering | Drill Extraction Wells, 6" diam, 20 ft depth | 2 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $50,000 | $50,000 |
| | 10 gpm submersible pumps | 2 | ea | | $300.00 | | | Vendor Quote | $0 | $600 | $0 | $0 | $600 |
| | PVC Piping to French Drain Sump, 2.5" | 400 | lf | $1.70 | | $2.19 | | Means Ref. | $680 | $0 | $876 | $0 | $1,556 |
| | | | | | | | | | | | | | |
| SVE System | Drill & Install Casing for Vapor Extraction Wells, 4"diam & 20' depth | 15 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $375,000 | $375,000 |
| | Vapor Extraction System | 2 | ea | | | | $5,280.00 | Vendor Quote | $0 | $0 | $0 | $10,560 | $10,560 |
| | 4" PVC Piping Including Fittings | 300 | lf | $3.41 | | $2.77 | | Means Ref. | $1,023 | $0 | $831 | $0 | $1,854 |
| | 6" PVC | 40 | lf | $5.25 | | $2.81 | | Means Ref. | $210 | $0 | $112 | $0 | $322 |
| | 4" Butterfly Valves, PVC | 3 | ea | $300.00 | | $100.00 | | Vendor Quote | $900 | $0 | $300 | $0 | $1,200 |
| | Manholes | 15 | ea | | | | $1,500.00 | Vendor Quote | $0 | $0 | $0 | $22,500 | $22,500 |
| | Vacuum Gagues | 15 | ea | | | | $150.00 | Vendor Quote | $0 | $0 | $0 | $2,250 | $2,250 |
| | Flow Element/Local Indicator | 3 | ea | | | | $2,000.00 | Vendor Quote | $0 | $0 | $0 | $6,000 | $6,000 |
| | Shed Housing SVE Pumps & Carbon Adsorption Equipment | 320 | sq ft | | | | $25.00 | Prof. Judgement | $0 | $0 | $0 | $8,000 | $8,000 |
| | Electric Heater | 1 | ea | | $350.00 | | | Vendor Quote | $0 | $350 | $0 | $0 | $350 |
| | | | | | | | | | | | | | |
| RF Heating Unit | Setup, Startup, & Testing | 1 | ls | | | | $80,000.00 | Vendor Quote | $0 | $0 | $0 | $80,000 | $80,000 |
| | Equipment Rental | 56 | wk | | | | $10,000.00 | Vendor Quote | $0 | $0 | $0 | $560,000 | $560,000 |
| | | | | | | | | | | | | | |
| Installation of Equipment | Installation Mechanical & Electrical | 64 | hrs | | | $35.00 | | Prof. Judgement | $0 | $0 | $2,240 | $0 | $2,240 |
| | Materials | 1 | ls | $400.00 | | | | Prof. Judgement | $400 | $0 | $0 | $0 | $400 |
| | | | | | | | | | | | | | |
| Off-gas Treatment | Carbon Adsorption System | 2 | ea | | $5,218.00 | | | Vendor Quote | $0 | $10,436 | $0 | $0 | $10,436 |
| | Initial Granular Activated Carbon (3,000 lbs | 1 | ls | $3,240.00 | | | | Vendor Quote | $3,240 | $0 | $0 | $0 | $3,240 |
| | | | | | | | | | | | | | |
| Drill Monitoring Wells | Drill & Case 4 wells, 6"diam. & 20'depth | 4 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $100,000 | $100,000 |
| | | | | | | | | | | | | | |
| Additional Field Personnel | Surveyor | 40 | hr | | | $50.00 | | Prof. Judgement | $0 | $0 | $2,000 | $0 | $2,000 |
| | Health & Safety | 16 | hr | | | $65.00 | | Prof. Judgement | $0 | $0 | $1,040 | $0 | $1,040 |
| | Geologist | 80 | hr | | | $55.00 | | Prof. Judgement | $0 | $0 | $4,400 | $0 | $4,400 |
| | | | | | | | | | | | | | |
| Well Closure (1) | Labor | 120 | hr | | | $35.00 | | Prof. Judgement | $0 | $0 | $3,615 | $0 | $3,615 |
| | Bentonite Grout Wells | 1.40 | CY | $54.00 | | | | Vendor Quote | $65 | $0 | $0 | $0 | $65 |
| | | | | | | | | | | | | | |
| Decommission French Drain (1) | Backhoe | 1 | day | | $2,200.00 | $382.00 | | Means Ref. | $0 | $1,894 | $312 | $0 | $2,205 |
| | | | | | | | | | | | | | |
| **Subtotal Direct Capital Costs** | | | | | | | | | $6,518 | $16,780 | $35,126 | $1,214,310 | $1,382,734 |
| | | | | | | | | | | | | | |
| **Indirect Capital Costs** | | | | | | | | | | | | | |
| Eng., Design & Inspection | 15% of direct materials, equipment, & labor | | | | | | | Facil. Eng. 009 | $978 | $2,517 | $3,769 | $0 | $7,264 |
| Misc. Labor & Materials | 10% of direct labor & $1.50 in materials cost for each direct labor hour | | | | | | | Facil. Eng. 009 | $780 | $0 | $2,513 | $0 | $3,293 |
| Permits | 5% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $326 | $839 | $1,256 | $0 | $2,421 |
| Construction Management | 10% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $652 | $1,678 | $2,513 | $0 | $4,842 |
| Project Management | 10% of direct materials, equipment, & labor ED&I | | | | | | | EG&G Cost Est. | $750 | $1,930 | $2,880 | $0 | $5,560 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor | | | | | | | Facil. Eng. 009 | $1,640 | $4,245 | $6,367 | $0 | $12,251 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $121,431 | $121,431 |

| Activity | Remedial Description | Qty | Unit | Bare Costs Per Unit: Mat'l | Equip. | Labor | Sub-contract | Source | Bare Costs: Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Subtotal Indirect Capital Costs** | | | | | | | | | $5,134 | $11,209 | $19,297 | $121,431 | $157,071 |
| | | | | | | | | | | | | | |
| **Contingency** | 30% of direct and indirect capital costs | | | | | | | Facil. Eng. 000 | $3,496 | $8,396 | $13,327 | $400 722 | $425,941 |
| | | | | | | | | | | | | | |
| **Total Capital Costs** | | | | | | | | | $15,146 | $36,395 | $57,749 | $1,736,483 | $1,845,745 |

| Activity | Remedial Description | Qty | Unit | Mat'l | Equip. | Labor | Sub-contract | Source | Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual O&M Direct Costs** | | | | | | | | | | | | | |
| Operations | Replacement Granular Activated Carbon | 9,000 | lb | $1.08 | | $1.25 | | Vendor Quote | $9,720 | $0 | $11,250 | $0 | $20,970 |
| | Transportation of Spent GAC | 4 | loads | | | | $2,700.00 | Vendor Quote | $0 | $0 | $0 | $10,800 | $10,800 |
| | Disposal of Granular Activated Carbon | 12,000 | lb | | | | $0.34 | Vendor Quote | $0 | $0 | $0 | $4,080 | $4,080 |
| | Electrical Costs of Vacuum Pumps | 36 | wk | $47.00 | | | | Prof. Judgement | $1,692 | $0 | $0 | $0 | $1,692 |
| | Electrical Costs of Heater | 24 | wks | $23.63 | | | | Prof. Judgement | $567 | $0 | $0 | $0 | $567 |
| | Electrical Costs of RF Unit (500 KW Unit) | 1 | yr | | | | $117,600.00 | Prof. Judgement | $0 | $0 | $0 | $117,600 | $117,600 |
| | Confirmatory Sampling | 80 | ea | | | | $150.00 | Prof. Judgement | $0 | $0 | $0 | $12,000 | $12,000 |
| | Groundwater Treatment @ IM/IRA Treat. Facil. | 1 | yr | | | | $676,000.00 | (2) | $0 | $0 | $0 | $676,000 | $676,000 |
| | | | | | | | | | | | | | |
| Maintenance | Labor | 192 | hr | | | $35.00 | | Prof. Judgement | $0 | $0 | $6,720 | $0 | $6,720 |
| | Materials & Parts | 12 | mo | $200.00 | | | | Prof. Judgement | $2,400 | $0 | $0 | $0 | $2,400 |
| | | | | | | | | | | | | | |
| Personnel | Operator | 4,160 | hr | | | $35.00 | | Prof. Judgement | $0 | $0 | $145,600 | $0 | $145,600 |
| | H&S | 96 | hr | | | $65.00 | | Prof. Judgement | $0 | $0 | $6,240 | $0 | $6,240 |
| | Geologist | 192 | hr | | | $55.00 | | Prof. Judgement | $0 | $0 | $10,560 | $0 | $10,560 |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **Subtotal O&M Direct Costs** | | | | | | | | | $14,379 | $0 | $180,370 | $820,480 | $1,015,229 |
| **Annual O&M Indirect Costs** | | | | | | | | | | | | | |
| Misc. Labor & Materials | 10% of direct labor & $1 50 in material cost for each direct labor hour | | | | | | | Facil. Eng. 000 | $6,960 | $0 | $18,037 | $0 | $24,997 |
| Project Management | 10% of direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $1,438 | $0 | $18,037 | $0 | $19,475 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor costs | | | | | | | Facil. Eng. 000 | $3,636 | $0 | $45,634 | $0 | $49,271 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $82,048 | $82,048 |
| **Subtotal O&M Indirect Costs** | | | | | | | | | $12,036 | $0 | $81 708 | $82,048 | $175,791 |
| | | | | | | | | | | | | | |
| **Contingency** | 30% of total direct and indirect O&M costs | | | | | | | Facil. Eng. 000 | $7,924 | $0 | $78,623 | $270 758 | $357,306 |
| | | | | | | | | | | | | | |
| **Total Annual O&M Cost** | | | | | | | | | $34,339 | $0 | $340,701 | $1 173,286 | $1,548,327 |
| | | | | | | | | | | | | | |
| **Total O&M Costs (expenditures occure in years 2-3 @ 5% discount rate) (3)** | | | | | | | | | $83,851 | $0 | $833,503 | $3,148,301 | $3,845,654 |

| Activity | Remedial Description | Qty | Unit | Mat'l | Equip. | Labor | Sub-contract | Source | Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual Post Closure Direct Costs** | | | | | | | | | | | | | |
| Semiannual Sampling | Collect Groundwater Samples | 12 | ea | | | | $1,500 00 | Prof. Judgement | $0 | $0 | $0 | $18,000 | $18,000 |
| Analytical Work | Sample Analysis for VOCs & Inorganics | 14 | ea | | | | $4,100.00 | Vendor Quote | $0 | $0 | $0 | $57,400 | $57,400 |
| **Subtotal Post Closure Direct Costs** | | | | | | | | | $0 | $0 | $0 | $75,400 | $75,400 |
| **Annual Post Closure Indirect Costs** | | | | | | | | | | | | | |
| Project Management | 10% of post closure direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $0 | $0 | $0 | $0 | $0 |
| Subcontractor Fee | 10% of post closure subcontractor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $7,540 | $7,540 |
| **Subtotal Post Closure Indirect Costs** | | | | | | | | | $0 | $0 | $0 | $7,540 | $7,540 |
| | | | | | | | | | | | | | |
| **Contingency** | 30% of total post closure direct and indirect costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $24 882 | $24 882 |
| | | | | | | | | | | | | | |
| **Total Annual Post Closure Costs** | | | | | | | | | $0 | $0 | $0 | $107,822 | $107,822 |
| | | | | | | | | | | | | | |
| **Total Post Closure Costs (continues for 30 yrs after completion of remedial action @ 5% discount rate)** | | | | | | | | | $0 | $0 | $0 | $1 811,696 | $1,811,696 |

| Activity | Resource Description | Qty | Unit | Bare Costs Per Unit | | | | Source | Bare Costs | | | | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Mat'l | Equip. | Labor | Sub-contract | | Mat'l | Equip. | Labor | Sub-contract | |
| **Total Cost Of Alternative** | | | | | | | | | $78,996 | $36,385 | $691,252 | $6 696 462 | $7 503 096 |

(1) Future Capital Cost that takes place upon completion of treatment. (Y 3 @ 5% discount rate total cost is in 1994 dollars)

(2) Costs represent annual operating costs as presented in the Phase I Preliminary Plan For Future Utilization of Existing Water Treatment Facilities At Rocky Flats Plant, Draft Report (June 15 1994)

(3) Operational expenses for the UV/peroxide water treatment plant during year 1 have been included in the total cost.

## Table E-7 Alternative 6 Hot Air Injection with Mechanical Mixing

| Activity | Resource Description | Qty | Unit | Bare Costs Per Unit: Mat'l | Bare Costs Per Unit: Equip. | Bare Costs Per Unit: Labor | Bare Costs Per Unit: Sub-contract | Source | Bare Costs: Mat'l | Bare Costs: Equip. | Bare Costs: Labor | Bare Costs: Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Direct Capital Costs** | | | | | | | | | | | | | |
| Soil Gas Survey | Geologist | 120 | hr | | | $55.00 | | Prof. Judgement | $0 | $0 | $6,600 | $0 | $6,600 |
| | Field Technician | 80 | hr | | | $35.00 | | Prof. Judgement | $0 | $0 | $2,800 | $0 | $2,800 |
| | Portable GC | 2 | wk | | $1,000.00 | | | Prof. Judgement | $0 | $2,000 | $0 | $0 | $2,000 |
| | Probes, Pump, and Misc. Equipment | 100 | ea | | $15.00 | | | Prof. Judgement | $0 | $1,500 | $0 | $0 | $1,500 |
| Dewatering | Drill Extraction Wells, 4" diam, 20 ft depth | 5 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $125,000 | $125,000 |
| | 5 gpm submersible pumps | 5 | ea | | $300.00 | | | Vendor Quote | $0 | $1,500 | $0 | $0 | $1,500 |
| | PVC Piping to French Drain Sump, 2.5" | 1000 | lf | $1.70 | | $2.19 | | Means Ref. | $1,700 | $0 | $2,190 | $0 | $3,890 |
| Treatment of Soils | Mechanical Mixing Tool (1) | 4,500 | cy | | | | $150.00 | Vendor Quote | $0 | $0 | $0 | $675,000 | $675,000 |
| Additional Field Personnel | Surveyor | 40 | hr | | | $50.00 | | Prof. Judgement | $0 | $0 | $2,000 | $0 | $2,000 |
| | Health & Safety | 16 | hr | | | $65.00 | | Prof. Judgement | $0 | $0 | $1,040 | $0 | $1,040 |
| | Geologist | 80 | hr | | | $55.00 | | Prof. Judgement | $0 | $0 | $4,400 | $0 | $4,400 |
| Drill Monitoring Wells | Drill & Case 4 wells, 6"diam. & 20'depth | 4 | ea | | | | $25,000.00 | Vendor Quote | $0 | $0 | $0 | $100,000 | $100,000 |
| Well Closure (2) | Labor | 50 | hr | | | $35.00 | | Prof. Judgement | $0 | $0 | $1,584 | $0 | $1,584 |
| | Bentonite Grout Wells | 0.40 | CY | $54.00 | | | | Vendor Quote | $20 | $0 | $0 | $0 | $20 |
| Decommission French Drain (2) | Backhoe | 1 | day | | $2,300.00 | $362.00 | | Means Ref. | $0 | $1,991 | $328 | $0 | $2,319 |
| **Subtotal Direct Capital Costs** | | | | | | | | | $1,720 | $6,991 | $20,941 | $900,000 | $920,652 |
| **Indirect Capital Costs** | | | | | | | | | | | | | |
| Eng., Design & Inspection | 15% of direct materials, equipment, & labor | | | | | | | Facil. Eng. 009 | $258 | $1,049 | $3,141 | $0 | $4,448 |
| Misc. Labor & Materials | 10% of direct labor & $1.50 in materials cost for each direct labor hour | | | | | | | Facil. Eng. 009 | $279 | $0 | $2,094 | $0 | $2,373 |
| Permits | 5% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $86 | $350 | $1,047 | $0 | $1,483 |
| Construction Management | 10% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $172 | $699 | $2,094 | $0 | $2,965 |
| Project Management | 10% of direct materials, equipment, & labor ED&I | | | | | | | EG&G Cost Est. | $198 | $804 | $2,408 | $0 | $3,410 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor | | | | | | | Facil. Eng. 009 | $435 | $1,769 | $5,298 | $0 | $7,502 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $90,000 | $90,000 |
| **Subtotal Indirect Capital Costs** | | | | | | | | | $1 428 | $4,670 | $16,083 | $90,000 | $112,181 |
| **Contingency** | 30% of direct and indirect capital costs | | | | | | | Facil. Eng. 009 | $944 | $3,498 | $11 107 | $297 000 | $312,550 |
| **Total Capital Costs** | | | | | | | | | $4,091 | $15,159 | $48,132 | $1,287,000 | $1,354,382 |

| Activity | Resource Description | Qty | Unit | Mat'l | Equip. | Labor | Sub-contract | Source | Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual O&M Direct Costs** | | | | | | | | | | | | | |
| Groundwater Treatment | Groundwater Treatment @ IM/IRA Treat. Facil. | 1 | yr | | | | $676,000.00 | (3) | $0 | $0 | $0 | $676,000 | $676,000 |
| **Subtotal O&M Direct Costs** | | | | | | | | | $0 | $0 | $0 | $676,000 | $676,000 |
| **Annual O&M Indirect Costs** | | | | | | | | | | | | | |
| Misc. Labor & Materials | 10% of direct labor & $1.50 in material cost for each direct labor hour | | | | | | | Facil. Eng 009 | $0 | $0 | $0 | $0 | $0 |
| Project Management | 10% of direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $0 | $0 | $0 | $0 | $0 |
| Overhead, Profit & Bond | 25.3% of direct materials, equipment, & labor costs | | | | | | | Facil. Eng 009 | $0 | $0 | $0 | $0 | $0 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng 009 | $0 | $0 | $0 | $67,600 | $67,600 |

| Activity | Resource Description | Qty | Unit | Bare Costs Per Unit: Mat'l | Bare Costs Per Unit: Equip. | Bare Costs Per Unit: Labor | Bare Costs Per Unit: Sub-contract | Source | Bare Costs: Mat'l | Bare Costs: Equip. | Bare Costs: Labor | Bare Costs: Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Subtotal O&M Indirect Costs | | | | | | | | | $0 | $0 | $0 | $67 600 | $67,600 |
| | | | | | | | | | | | | | |
| Contingency | 30% of total direct and indirect O&M costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $223 080 | $223 080 |
| | | | | | | | | | | | | | |
| Total Annual O&M Cost | | | | | | | | | $0 | $0 | $0 | $966,680 | $966,680 |
| | | | | | | | | | | | | | |
| Total O&M Costs (expenditure occures in Yrs 1 & 2 @ 5% discount rate) | | | | | | | | | $0 | $0 | $0 | $1,887,328 | $1,887,328 |

| Activity | Resource Description | Qty | Unit | Mat'l | Equip. | Labor | Sub-contract | Source | Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Annual Post Closure Direct Costs | | | | | | | | | | | | | |
| Semiannual Sampling | Collect Groundwater Samples | 12 | ea | | | | $1,500.00 | Prof. Judgement | $0 | $0 | $0 | $18,000 | $18,000 |
| Analytical Work | Sample Analysis for VOCs & Inorganics | 14 | ea | | | | $4,100.00 | Vendor Quote | $0 | $0 | $0 | $57,400 | $57,400 |
| Subtotal Post Closure Direct Costs | | | | | | | | | $0 | $0 | $0 | $75,400 | $75,400 |
| Annual Post Closure Indirect Costs | | | | | | | | | | | | | |
| Project Management | 10% of post closure direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $0 | $0 | $0 | $0 | $0 |
| Subcontractor Fee | 10% of post closure subcontractor costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $7,540 | $7,540 |
| Subtotal Post Closure Indirect Costs | | | | | | | | | $0 | $0 | $0 | $7,540 | $7,540 |
| | | | | | | | | | | | | | |
| Contingency | 30% of total post closure direct and indirect costs | | | | | | | Facil. Eng. 000 | $0 | $0 | $0 | $24,882 | $24,882 |
| | | | | | | | | | | | | | |
| Total Annual Post Closure Costs | | | | | | | | | $0 | $0 | $0 | $107 822 | $107,822 |
| | | | | | | | | | | | | | |
| Total Post Closure Costs (30 yrs @ 5% discount rate) | | | | | | | | | $0 | $0 | $0 | $1 789 070 | $1 789,070 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Total Cost Of Alternative | | $4,091 | $15 159 | $48,132 | $4 963 398 | $5 030 780 |

(1) Cost includes vapor treatment and confirmatory samples.

(2) Future capital cost that takes place upon completion of treatment. (Y 2 @ 5% discount rate total cost is in 1994 dollars)

(3) Costs represent annual operating costs as presented in the Phase I Preliminary Plan For Future Utilization of Existing Water Treatment Facilities At Rocky Flats Plant, Draft Report (June 15 1994)

## Table E-8 Alternative7 Soil Excavation and Groundwater Removal With Sump Pumps

| Activity | Resource Description | Qty | Unit | Bare Costs Per Unit: Mat'l | Bare Costs Per Unit: Equip. | Bare Costs Per Unit: Labor | Bare Costs Per Unit: Sub-contract | Source | Bare Costs: Mat'l | Bare Costs: Equip. | Bare Costs: Labor | Bare Costs: Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Direct Capital Costs** | | | | | | | | | | | | | |
| Construct Staging Area | Towed Sheepsfoot | 404 | CY | | $0 70 | $0.30 | | Means Ref. | $0 | $283 | $81 | $0 | $364 |
| | Base Course | 1003 | SY | $2.12 | $0.29 | $0.22 | | Means Ref. | $2,126 | $291 | $221 | $0 | $2,638 |
| | Reinforced Concrete Slab, 6" Thick | 104 | CY | $88.28 | $9.09 | $72.52 | | Means Ref. | $9,181 | $945 | $7,542 | $0 | $17,669 |
| | Submersible Sump Pump, 5 gpm | 2 | ea | | $300.00 | | | Vendor Quote | $0 | $600 | $0 | $0 | $600 |
| | 2" PVC Piping (including fittings) | 200 | lf | $1 44 | | $2.04 | | Means Ref. | $288 | $0 | $408 | $0 | $696 |
| | | | | | | | | | | | | | |
| Scrape Top Soil & Stockpile | Towed Scraper | 323 | CY | | $3 45 | $0.81 | | Means Ref. | $0 | $1,114 | $262 | $0 | $1,376 |
| | | | | | | | | | | | | | |
| Dust Control | Water Truck, 5,000 gal capacity | 1,440 | hr | | $21.32 | $25.00 | | Means Ref. | $0 | $30,701 | $36,000 | $0 | $66,701 |
| | | | | | | | | | | | | | |
| Excavate Soil, Haul to Staging Area | Dozer | 22,630 | CY | | $2.91 | $0.64 | | Means Ref. | $0 | $65,863 | $14,483 | $0 | $80,337 |
| | Backhoe | 1,132 | CY | | $0.98 | $0.37 | | Means Ref. | $0 | $1,109 | $419 | $0 | $1,528 |
| | Front End Loader | 21,400 | CY | | $0.66 | $0.35 | | Means Ref. | $0 | $14,189 | $7,525 | $0 | $21,714 |
| | Dump Trailer | 22,630 | CY | | $1.15 | $0.46 | | Means Ref. | $0 | $26,025 | $10,410 | $0 | $36,434 |
| | | | | | | | | | | | | | |
| Dewatering | 20 gpm Suction Pumps | 2 | ea | | $400 00 | | | Vendor Quote | $0 | $800 | $0 | $0 | $800 |
| | 2.5" PVC Pipe (includes fittings) | 200 | lf | $1.70 | | $2.19 | | Means Ref. | $340 | $0 | $438 | $0 | $778 |
| | Corrugated Metal Pipe | 12 | lf | $4.15 | | $1.40 | | Means Ref. | $50 | $0 | $17 | $0 | $67 |
| | Pea Gravel | 30 | CY | $17.55 | | | | Means Ref. | $527 | $0 | $0 | $0 | $527 |
| | | | | | | | | | | | | | |
| Rad Screening of Soils | Health & Safety Specialist | 1,440 | hr | | | $56.00 | | EG&G Rad Eng. | $0 | $0 | $80 640 | $0 | $80,640 |
| | Monitoring Equipment Maintenance | 180 | hr | | | $55.00 | | EG&G Rad Eng. | $0 | $0 | $9,900 | $0 | $9,900 |
| | | | | | | | | | | | | | |
| Treatment of Excavated Soils | Thermal Desorption Unit | 22,630 | CY | | | | $75 00 | Vendor Quote | $0 | $0 | $0 | $1,697 250 | $1,697,250 |
| | Thermal Desorption Unit Mobilization | 1 | ls | | | | $4,000 00 | Vendor Quote | $0 | $0 | $0 | $4 000 | $4 000 |
| | Thermal Desorption Unit Demobilization | 1 | ls | | | | $1,500.00 | Vendor Quote | $0 | $0 | $0 | $1 500 | $1,500 |
| | Wheel Mounted Front End Loader | 45,260 | CY | | $0.66 | $0.35 | | Means Ref. | $0 | $29,872 | $15 841 | $0 | $45 713 |
| | | | | | | | | | | | | | |
| Transportation/Disposal of Soil | Transportation to Disposal Facility ( 50 mi) | 22,630 | CY | | | | $53 00 | Vendor Quote | $0 | $0 | $0 | $1 199 390 | $1 199 390 |
| | Disposal at Licensed Facility | 22,630 | CY | | | | $123.00 | Vendor Quote | $0 | $0 | $0 | $2 783,490 | $2,783 490 |
| | Soil Samples | 1,886 | ea | | | | $250.00 | Prof Judgement | $0 | $0 | $0 | $471 458 | $471 458 |
| | | | | | | | | | | | | | |
| Groundwater Treatment | UV/Peroxide & IX Treatment System | 1 | yr | | | | $676,000.00 | (1) | $0 | $0 | $0 | $676,000 | $676,000 |
| | | | | | | | | | | | | | |
| Backfill Excavation | Pit-Run Fill/Gravel, 5 mi haul | 22,630 | CY | $3 57 | $4 86 | $1 83 | | Means Ref. | $80,789 | $109 982 | $41 413 | $0 | $232,184 |
| | Towed Sheepsfoot, 12" lifts | 22,630 | CY | | $0 35 | $0.09 | | Means Ref. | $0 | $7 921 | $2,037 | $0 | $9 957 |
| | Revegetation | 2,904 | SY | $0.22 | $0.06 | $0.06 | | Means Ref. | $639 | $174 | $174 | $0 | $987 |
| | | | | | | | | | | | | | |
| Decommission French Drain | Backhoe | 1 | day | | $2,200 | $362.00 | | Means Ref. | $0 | $2,200 | $362 | $0 | $2,562 |
| | | | | | | | | | | | | | |
| Drill Monitoring Wells | Drill & Case 4 wells, 6"diam. & 20'depth | 4 | ea | | | | $25,000 00 | Vendor Quote | $0 | $0 | $0 | $100 000 | $100 000 |
| | | | | | | | | | | | | | |
| Additional Field Personnel | Sr Geologist | 110 | hrs | | | $75 00 | | Prof Judgement | $0 | $0 | $8,250 | $0 | $8 250 |
| | Surveyor | 100 | hrs | | | $50.00 | | Prof Judgement | $0 | $0 | $5 000 | $0 | $5 000 |
| | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| Confirmatory Sampling | Soil Samples From Excavation Site | 25 | ea | | | | $250 00 | Prof Judgement | $0 | $0 | $0 | $6,250 | $6 250 |
| | | | | | | | | | | | | | |
| **Subtotal Direct Capital Costs** | | | | | | | | | $93,940 | $292,059 | $241,421 | $6 939,338 | $7,555,508 |
| **Indirect Capital Costs** | | | | | | | | | | | | | |
| Engineering, Design & Inspection | 15% of direct materials, equipment, & labor | | | | | | | Facil. Eng 009 | $14 091 | $43 809 | $36,213 | $0 | $94,113 |
| Miscellaneous Labor & Materials | 10% of direct labor & $1 50 in materials cost for each direct labor hour | | | | | | | Facil. Eng 009 | $8,403 | $0 | $24 142 | $0 | $32,545 |

| Activity | Resource Description | Qty | Unit | Bare Costs Per Unit Mat'l | Equip. | Labor | Sub-contract | Source | Bare Costs Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Permits | 5% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $4,697 | $14 603 | $12,071 | $0 | $31,371 |
| Construction Management | 10% of direct materials, equipment, & labor | | | | | | | Prof. Judgement | $9,394 | $29 206 | $24 142 | $0 | $62,742 |
| Project Management | 10% of direct materials, equipment, & labor ED&I | | | | | | | EG&G Cost Est. | $10,803 | $33,587 | $27,763 | $0 | $72,153 |
| Overhead, Profit & Bond | 25 3% of direct materials, equipment, & labor | | | | | | | Facil. Eng. 009 | $23,767 | $73,891 | $61,080 | $0 | $158 737 |
| Subcontractor Fee | 10% of subcontractor costs | | | | | | | Facil. Eng 009 | $0 | $0 | $0 | $693,934 | $693,934 |
| **Subtotal Indirect Capital Costs** | | | | | | | | | $71,155 | $196,066 | $185 412 | $693 934 | $1 145,596 |
| | | | | | | | | | | | | | |
| **Contingency** | 30% of direct and indirect capital costs | | | | | | | Facil. Eng. 009 | $49 526 | $146,146 | $128 050 | $2 289,962 | $2 613,706 |
| | | | | | | | | | | | | | |
| **Total Capital Costs** | | | | | | | | | $314,623 | $633,300 | $554,863 | $9,923,254 | $11,326,060 |

| Activity | Resource Description | Qty | Unit | Mat'l | Equip. | Labor | Sub-contract | Source | Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual O&M Direct Costs** | | | | | | | | | | | | | |
| | | | | | | | | | | | | | |
| **Subtotal O&M Direct Costs** | | | | | | | | | $0 | $0 | $0 | $0 | $0 |
| | | | | | | | | | | | | | |
| **Total O&M Costs** | | | | | | | | | $0 | $0 | $0 | $0 | $0 |

| Activity | Resource Description | Qty | Unit | Mat'l | Equip. | Labor | Sub-contract | Source | Mat'l | Equip. | Labor | Sub-contract | Total Costs |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Annual Post Closure Direct Costs** | | | | | | | | | | | | | |
| Semiannual Sampling | Collect Groundwater Samples | 12 | ea | | | | $1,500 00 | Prof. Judgement | $0 | $0 | $0 | $18,000 | $18,000 |
| Groundwater Monitoring | Semiannual Groundwater Sampling | 14 | ea | | | | $4,100 00 | Vendor Quote | $0 | $0 | $0 | $57,400 | $57 400 |
| Revegitation | 10% of Excavated Area/yr | 290 | SY | $0.22 | $0.06 | $0.06 | | Means Ref | $64 | $17 | $17 | $0 | $99 |
| **Subtotal Post Closure Direct Costs** | | | | | | | | | $64 | $17 | $17 | $75,400 | $75,499 |
| **Annual Post Closure Indirect Costs** | | | | | | | | | | | | | |
| Project Management | 10% of post closure direct materials, equipment, & labor costs | | | | | | | EG&G Cost Est. | $6 | $2 | $2 | $0 | $10 |
| Subcontractor Fee | 10% of post closure subcontractor costs | | | | | | | Facil. Eng. 009 | $0 | $0 | $0 | $7,540 | $7,540 |
| **Subtotal Post Closure Indirect Costs** | | | | | | | | | $6 | $2 | $2 | $7 540 | $7,550 |
| | | | | | | | | | | | | | |
| **Contingency** | 30% of total post closure direct and indirect costs | | | | | | | Facil. Eng. 009 | $21 | $6 | $6 | $24 882 | $24,915 |
| | | | | | | | | | | | | | |
| Total Annual Post Closure Costs | | | | | | | | | $91 | $25 | $25 | $107,822 | $107,963 |
| | | | | | | | | | | | | | |
| **Total Post Closure Costs (30 yr @ 5% discount rate)** | | | | | | | | | $1,494 | $407 | $407 | $1,765,310 | $1,767,619 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Total Cost Of Alternative** | | $216,117 | $633,708 | $555,290 | $11 688,564 | $13,093,679 |

(1) Cost represents annual operating cost as presented in the Phase I Preliminary Plan for Future Utilization of Existing Water Treatment Facilities at Rocky Flats Plant, Draft Report (June 15, 1994)
It has been assumed for cost estimating purposes that the French Drain and OU 1 Water Treatment Plant will operate for one year during excavation and treatment.

# OU-1 DOMESTIC WATER SUPPLY SIMULATIONS

**The results of computer simulations of domestic water production capabilities from subsurface units beneath OU 1 at the Rocky Flats Plant Golden Colorado**

This work was performed by the Geosciences Division in support of risk analysis studies

December 14 1992

## INTRODUCTION

To investigate the water production capabilities of the colluvial materials beneath Operable unit 1 at the Rocky Flats Plant several transient pumping computer simulations were performed These simulations were designed to determine whether these saturated materials could produce sufficient water to supply a hypothetical four member household A daily pumping requirement of 240 gallons per day (gpd) was assumed based on a daily water requirement of 60 gallons per person

## METHOD

Simulations were performed using the USGS MODFLOW groundwater flow simulation package (McDonald and Harbaugh 1988) Input parameters common to all simulations are listed in Table 1 Simulations were run using a daily time frame until the pumping well grid cell went dry or the end of the simulation (365 days) was reached

The pumping well was located at the center of the 19 by 19 grid cell array A variable grid spacing ranging from 5 feet at the well to 50 feet at the boundaries was used to provide realistic drawdown conditions near the well The grid spacing for each scenario are given in Table 1 and shown in Figure 1 The specific yield came from lab analyses of core samples and example values from the literature for fine grained materials (Fetter 1980 pg 68) Boundary conditions were constant head equal to the initial head

Table 1

| PARAMETER | VALUE | SOURCE |
|---|---|---|
| Hydraulic Conductivity | 1E 4 to 1E 5 cm/sec | Table 3 6 of OU1 Phase III Report |
| Specific Yield | 0 10 | Lab analyses/literature |
| Grid Spacing (variable) | from 5 to 50 ft | Assumed |
| Hydrogeologic Unit Character | Unconfined | On site observation |
| Initial Saturated Thickness | 10 ft | Figure 3 36 of OU1 Phase III Report |
| Boundary Conditions | Constant head | Assumed |

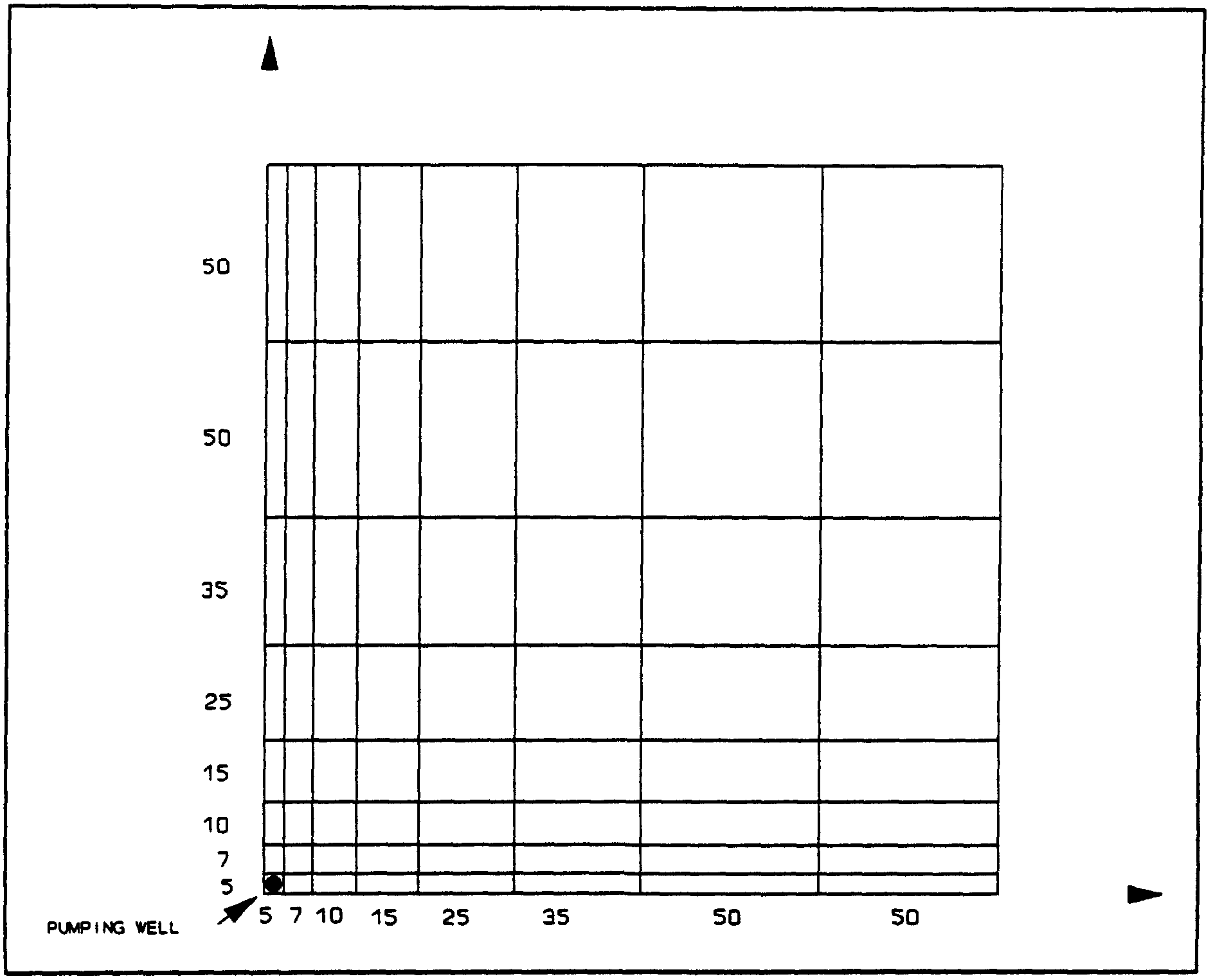


**Figure 1** Figure shows 1/4 (upper right hand quadrant) of an example model grid In model well is at center of grid Grid spacings in feet The number of grid nodes for each model may differ but grid spacings are similar Not to scale

## 1 5 GPM SCENARIO

For this scenario a pumping rate of 1 5 gpm was used This rate is below the 3 5 gpm rate commonly used for domestic wells and as such is conservative Each day of the transient simulation was divided into two stress periods and each period was divided into two timesteps The first 2 7 hours of each day was used as a pumping period It was assumed that the household maintained water storage capabilities and that this pumping period was used to replenish the water storage system The pumping period was based on the total daily water requirement (240 gal ) and the pumping rate (1 5 gpm)

$$240 \text{ gal}/(1\ 5 \text{ gal/min} \bullet 60 \text{ min/hr}) = 2\ 7 \text{ hrs}$$

The remaining 21 3 hours of each day allowed water level recovery to take place

To determine the effect of uncertainty in hydraulic conductivity two simulations with different conductivity parameters were run The results from these simulations are shown in the following table

Summary of simulation results for 1 5 gpm scenario

| HYDRAULIC CONDUCTIVITY (CM/SEC) | WATER PRODUCTION DAYS |
|---|---|
| 1E 5 | <1 |
| 1E 4 | <1 |

**Results**

For the 1 5 gpm scenario the pumping well grid cell went dry within the first day of the simulation regardless of which hydraulic conductivity was used This is consistent with the low hydraulic conductivity and small saturated thickness observed for 881 Hillside colluvial materials

## MAXIMUM POTENTIAL WATER PRODUCTION

To further investigate the potential for water production from the colluvial materials on the 881 Hillside several simulations with differing pumping rates were performed These simulations were not designed to produce 240 gallons of water per day but instead were intended to determine a potential maximum water production For this reason each day of the transient simulation was divided into two stress periods with each period divided into two timesteps The first 12 hour stress period was a pumping period and second 12 hour segment was a recovery phase Again two different hydraulic conductivities were examined All other simulation parameters are as listed in Table 1 and shown in Figure 1

Results from simulations with a hydraulic conductivity of **1e-4 cm/sec** are shown in the following table Each row represents a different pumping rate (given both in cubic feet per day and gallons per minute) The "Daily Water Production column gives the equivalent daily water production rate in gallons This is the rate at which water was being produced prior to any desaturation of the well cell within the model and assumes a 12 hour pumping period The "Water Production Days column gives the number of simulated days before the well cell was desaturated (dried up) Values for "Water Production Days" greater than 365 indicate the well cell did not desaturate during the simulation

Simulation Results with K = 1e 4 cm/sec

| PUMPING RATE FT^3/DAY | PUMPING RATE GPM | DAILY WATER PRODUCTION (GAL ) | WATER PRODUCTION DAYS |
|---|---|---|---|
| 100 | 0 52 | 374 | < 1 |
| 50 | 0 26 | 187 | 3 5 |
| 35 | 0 18 | 130 | 43 5 |
| 30 | 0 16 | 115 | 221 5 |
| 27 | 0 14 | 101 | > 365 |

Results from simulations with a hydraulic conductivity of 1e 5 cm/sec are shown in the following table  Column and row descriptions are as listed for the previous table  Note that pumping rates are lower than those in the previous simulation

Simulation Results with K = 1e 5 cm/sec

| PUMPING RATE FT^3/DAY | PUMPING RATE GPM | DAILY WATER PRODUCTION (GAL ) | WATER PRODUCTION DAYS |
|---|---|---|---|
| 27 | 0 14 | 101 | 2 25 |
| 10 | 0 052 | 37 | 9 25 |
| 5 | 0 026 | 19 | 70 5 |
| 2 5 | 0 013 | 9 | > 365 |

An additional simulation was run using a hydraulic conductivity based on OU 1 field measurements  The geometric mean of single well tests in colluvial materials was 1 75E 05 cm/sec  Using this K and the same values presented for other parameters  gives a maximum pumping rate of 6 0 $ft^3$/day (or 22 4 gallons per day) for a 12 hour pump period without desaturating the well

**Results**

The results from these simulations to investigate the maximum potential water production capabilities from the 881 Hillside colluvium indicate maximum expected production capabilities that are less than 10% of that required to supply a family of four (240 gallons)  In reality long term production rates would be lower because of the constant head boundary conditions assumed in the model  This type of boundary condition would represent an infinte water source to the well given a sufficently low pumping rate  Actual field conditons on the 881 Hillside consist of saturated regions often surrounded by desaturated zones which would limit long term water production capabilities  The simulation also assumed a consant saturated thickness across the model domain  Field data from the 881 Hillside indicate that the thickness of saturated colluvium varies  often thinning below the 10 foot saturated thickness assumed in the modeling  The combination of these factors suggest that the model determined pumping rates would be higher than would be expected from an actual water production well on the 881 Hillside

References

Fetter C W Jr 1980 Applied Hydrogeology Merrill Publishing Company Columbus 488 p

McDonald Michael G and Harbaugh Arlen W 1988 Techniques of Water Resources Investigations of the United States Geological Survey Book 6 Chapter A1 A Modular Three dimensional Finite difference Groundwater Flow Model

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March 12 1992

Mr Scott Grace
United States Department of Enero/
Rocky Flats Office
P O Boy 928
Golden CO 80402-0928

Dear Mr Grace

We have reviewed the document submitted entitled Public Health Risk Assessment 881 Hillside Area (OU1) Technical Memorandum No 6 Exposure Scenarios Revision 3 0 dated March 1992 The purpose of our review was to specifically evaluate the findings presented in Appendix B Investigation and Simulation of Water Production Capabilities

The basic conclusion of this appendix is that neither the shallow alluvial aquifer (Rocky Flats Alluvium) nor the underlying Arapahoe Aquifer is capable of producing sufficient water for even domestic purposes This conclusion was derived from model simulation runs utilizing the USGS MODFLOW ground water flow simulation package This conclusion is applied only to the 881 Hillside area

While the basic input parameters are given in the appendix actual model setup and output were not submitted Basically the parameters selected and presented in Table B-3 and Table B-4 appear to be reasonable with the exception of the specific yield value for the Arapahoe Aquifer Based on previous work by the USGS and on researched funded by this office and the Colorado Water Conservation Board, the actual specific yield of the Arapahoe Aquifer ranges between 0 15 and 0 20 The simulation runs used a value of 0 30 The use of the higher value will result in more water being released from storage and a more rapid depletion This will cause cells to dry up more quickly than they may in actuality Although we suggest that the model be rerun with a specific yield of no more than 0 20 we do not feel that the result will significantly change the conclusion It will change the length of time necessary to deplete cells

Based on these comments we feel that the conclusion that neither aquifer is a potential source for domestic water supplies in the 881 Hillside area is valid when considering future land use

We would like to comment on several statements made in the document which are not necessarily correct and should be corrected prior to issuance of the final document

1 Page B-5 Paragraph 4 -- This paragraph states that domestic wells drilled to the Laramie-Fox Hills Aquifer (500 to 700 feet) are not an economically viable alternative This is not true It is quite common in the Denver Basin for domestic wells to be drilled to depths in excess of 1000 feet Therefore Laramie-Fox Hills wells for domestic purposes are <u>very</u> likely in the future depending on the permitted land use

2 Page B-8, last paragraph -- It is stated that well yields listed in Table B-5 are the maximum permissible pumping rates Actually the rates listed for the domestic wells are those reported by the driller at the time the well was completed and actual <u>permissible</u> pumping rates may be either 15 gpm or 25 gpm depending on the year the well was permitted It is true that the permissible rate is independent of the actual sustained yield Permitted pumping rates for wells other than domestic and stock (permit numbers with the suffix F ) may also be different than either the maximum pumping rate or the sustained yield

3 Page B-13 first paragraph -- Permitted well yields of less than 15 gpm do not necessarily mean that a well is limited to domestic or stock use

4 Page B-17 last paragraph -- It is stated that the bedrock dips approximately 1 degree However Page 2 states that the dip is 2 degrees

We hope that these comments are helpful Should you have any questions please contact me at (303) 866-3585

Sincerely,

George D VanSlyke
Chief Geotechnical Services

cc Hal Simpson, Acting State Engineer
Gary Baughman Colorado Department of Health Rocky Flats Unit
Ron Cattani Executive Director s Office CDNR

# AQUIFER PUMPING TEST DATA SHEET

DATE 5 \ 21 \ 92 PERSON RECORDING DATA R Smith - EG&G

WELL # 0487 (881 Hillside)

HYDROSTRATIGRAPHIC UNIT Colluvium

SCREENED INTERVAL 9.94 ft to 21.49 ft from TOC-SS (saturated screened interval)

STATIC WATER LEVEL 9.94 ft @ TOC-SS PUMPING WELL I.D. 2 in (casing)

DISTANCE TO PUMPING WELL N/A ft WELL TD 21.94 ft @ TOC-SS

pump intake depth 21.17 ft

TEST START TIME 13 19 55 initial saturated thickness 12.00 ft

| ELAPSED TIME (Units) (min) | Pump on/off | Volume pumped (gals) ~~WATER LEVEL~~ (Units) | ΔT (min) | Average Q (pumping well) (Units) (gpm) | Water Lev Lig |
|---|---|---|---|---|---|
| 0 0 | ON | | | | 9.94 |
| 1.22 | OFF | 3.05 | 1.22 | 2.5 | |
| 3.22 | ON | | | | |
| 4.08 | OFF | 0 | (pump | not priming) | |
| 8.58 | ON | | | | |
| 9.15 | OFF | 0.75 | 7.93 | 0.09 | |
| 11.08 | ON | | | | |
| 12.58 | OFF | 0 | (pump | not priming) | |
| 16.08 | ON | | | | |
| 17.53 | OFF | 0.5 | 8.38 | 0.060 | |
| 24.58 | ON | | | | |
| 26.42 | OFF | 0.5 | 8.89 | 0.056 | |
| 34.58 | ON | | | | |

# AQUIFER PUMPING TEST DATA SHEET

DATE 5/21/92 PERSON RECORDING DATA ________

WELL # 0497

HYDROSTRATIGRAPHIC UNIT (see Page 1)

SCREENED INTERVAL ____ft to ____ft

STATIC WATER LEVEL ____ft PUMPING WELL I.D. ____in

DISTANCE TO PUMPING WELL ____ft

TEST START TIME ____ ____ ____

| ELAPSED TIME (Units) (min) | Pump on/off | VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units) | ΔT (mv) | AVERAGE Q (pumping well) (Units) (gpm) | WATER LEV L(ft) |
|---|---|---|---|---|---|
| 36.05 | OFF | 0.5 | 9.63 | 0.052 | |
| 45.58 | ON | | | | |
| 46.77 | OFF | 0.5 | 10.72 | 0.047 | |
| 56.92 | ON | | | | |
| 57.30 | OFF | 0.45 | 10.52 | 0.043 | |
| 68.58 | ON | | | | |
| 70.16 | OFF | 0.5 | 12.86 | 0.039 | |
| 82.75 | ON | | | | |
| 84.50 | OFF | 0.6 | 14.34 | 0.042 | |
| 97.58 | ON | | | | |
| END OF TEST 99.42 (0) | OFF | 0.65 | 14.92 | 0.044 | |
| 101.25 (1.83) | | (RECOVERY DATA) | | | 21.28 |
| 102.33 (2.91) | | | | | 20.98 |

(4011)(AQTEST)(10/9/91)

# AQUIFER PUMPING TEST DATA SHEET

DATE 5\21\92 PERSON RECORDING DATA ____________

WELL # 0487

HYDROSTRATIGRAPHIC UNIT ____________ (see Page 1)

SCREENED INTERVAL ______ ft to ______ ft

STATIC WATER LEVEL ______ ft PUMPING WELL I.D ______ in

DISTANCE TO PUMPING WELL ______ ft

TEST START TIME ____ ____ ____

| ELAPSED TIME (Units)(min) | ELAPSED RECOVERY TIME | Pump on/off | VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units) | ΔT (min) | AVERAGE Q (pumping well) (Units)(gpm) | WATER LEVEL (ft) |
|---|---|---|---|---|---|---|
| 103 42 | (4.0) | | (RECOVERY DATA) | | | 20 65 |
| 104 42 | (5.0) | | | | | 20,40 |
| 105 42 | (6 0) | | | | | 20 10 |
| 106 42 | (7 0) | | | | | 19.86 |
| 107.42 | (8.0) | | | | | 19.59 |
| 108 42 | (9 0) | | | | | 19 32 |
| 109 42 | (10 0) | | | | | 19 06 |
| 110 42 | (11 0) | | | | | 18 81 |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |
| | | | | | | |

| EG&G ROCKY FLATS PLANT | Manual | 5 2100-OPS |
|---|---|---|
| EM/ER GROUNDWATER SOP | Procedure No | GW 08 Rev 0 |
| | Page | 33 of 43 |
| Safety Related | Effective Date | October 29 1991 |
| Category 1 | Organization | ER&WM |

# AQUIFER PUMPING TEST DATA SHEET

DATE 5\21\92 PERSON RECORDING DATA R Smith - EG&G

WELL # 37191 (881 Hillside)
HYDROSTRATIGRAPHIC UNIT Colluvium
SCREENED INTERVAL 13 9 ft to 23 8 ft From TOC-PVC

STATIC WATER LEVEL 7,55 ft @ TOC-PVC PUMPING WELL I.D 2 in (casing)

DISTANCE TO PUMPING WELL N/A ft WELL T.D 25 80 ft @ TOC-PVC

Pump intake depth 25 03 ft

TEST START TIME 09 38 25 Initial saturated thickness 17 25

| ELAPSED TIME (Units) (min) | Pump on/off | Volume pumped (gals) ~~WATER LEVEL~~ (Units) | ΔT (min) | Average Q (pumping well) (Units) (gpm) | Water lev ... |
|---|---|---|---|---|---|
| 0 0 | ON | | | | 7 55 |
| 2 5 | OFF | 3 0 | 2 5 | 1 20 | |
| 4 5 | ON | | | | |
| 5.5 | OFF | 1,2 | 3 0 | 0 40 | |
| 7 5 | ON | | | | |
| 8 25 | OFF | 1 0 | 2 75 | 0 36 | |
| 10 25 | ON | | | | |
| 11 41 | OFF | 0 5 | 3.16 | 0 10 | |
| 14 41 | ON | | | | |
| 15 24 | OFF | 0 4 | 3 83 | 0 10 | |
| 19,24 | ON | | | | |
| 19.74 | OFF | 0 4 | 4 50 | 0 09 | |
| 24 74 | ON | | | | |

Page 2 of 4



# AQUIFER PUMPING TEST DATA SHEET

DATE 5 \ 21 \ 92 PERSON RECORDING DATA ____________

WELL # 37191

(SEE Page 1)

~~HYDROSTRATIGRAPHIC UNIT ____________~~

~~SCREENED INTERVAL ______ ft to ______ ft~~

~~STATIC WATER LEVEL ______ ft~~ PUMPING WELL I.D ______ in

~~DISTANCE TO PUMPING WELL ______ ft~~

~~TEST START TIME ____ ____ ____~~

| ELAPSED TIME (Units) (min) | Pump ON/OFF | VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units) | ΔT (min) | AVERAGE Q (pumping well) (Units) (gpm) | WATER LEV. LIFT |
|---|---|---|---|---|---|
| 25.07 | OFF | 0 3 | 5 33 | 0 056 | |
| 33 07 | ON | | | | |
| 33.66 | OFF | 0 5 | 8 59 | 0 058 | |
| 39.66 | ON | | | | |
| 40.32 | OFF | 0 5 | 6 66 | 0 075 | |
| 47.33 | ON | | | | |
| 48.25 | OFF | 0 4 | 7 93 | 0 050 | |
| 57.25 | ON | | | | |
| 58.16 | OFF | 0 55 | 9.91 | 0 055 | |
| 67.16 | ON | | | | |
| 68.07 | OFF | 0 5 | 9.91 | 0 050 | |
| 78.08 | ON | | | | |
| 78.86 | OFF | 0 5 | 10.79 | 0 046 | |

# AQUIFER PUMPING TEST DATA SHEET

DATE 5\21\92 PERSON RECORDING DATA ______

WELL # 37191
HYDROSTRATIGRAPHIC UNIT ______ (see page 1)
SCREENED INTERVAL ______ ft to ______ ft

STATIC WATER LEVEL ______ ft PUMPING WELL I.D ______ in

DISTANCE TO PUMPING WELL ______ ft

TEST START TIME ______

| ELAPSED TIME (Units) (min) / ELAPSED RECOVERY TIME | Pump on/off | VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units) | ΔT (min) | AVERAGE Q (pumping well) (Units) (gpm) | WATER LEV LIF |
|---|---|---|---|---|---|
| 90.87 | ON | | | | |
| 91.87 | OFF | 0 6 | 13 01 | 0 046 | |
| 104 87 | ON | | | | |
| 105.87 | OFF | 0 75 | 14.00 | 0.054 | |
| 116.87 | ON | | | | |
| END OF TEST 118 55 (0) | OFF | 0 70 | 12 68 | 0 055 | |
| 119.83 (1 28) | | (RECOVERY DATA) | | | 24 40 |
| 120 83 (2 28) | | | | | 23 71 |
| 121.83 (3 28) | | | | | 23.19 |
| 122 83 (4 28) | | | | | 22 79 |
| 123 83 (5 28) | | | | | 22 36 |
| 124 83 (6 28) | | | | | 22 08 |
| 125 83 (7 28) | | | | | 21.75 |

# AQUIFER PUMPING TEST DATA SHEET

DATE 5\21\92 PERSON RECORDING DATA ____________

WELL # 37191
HYDROSTRATIGRAPHIC UNIT ____________ (see page 1)
SCREENED INTERVAL ______ ft to ______ ft

STATIC WATER LEVEL ______ ft PUMPING WELL I.D ______ in

DISTANCE TO PUMPING WELL ______ ft

TEST START TIME ______ ______ ______

| ELAPSED TIME (Units) (min) / ELAPSED RECOVERY TIME | Pump on/off | ~~WATER LEVEL~~ VOLUME PUMPED (gals) (Units) | ΔT (min) | AVERAGE Q (pumping well) (Units) (gpm) | WATER LEVEL (ft) |
|---|---|---|---|---|---|
| 126 83 (8 28) | | (RECOVERY | DATA) | | 21 57 |
| 127 83 (9 28) | | | | | 21,49 |
| 128 83 (10 28) | | | | | 21 43 |
| 130 83 (12 28) | | | | | 21 69 |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

(4011X\QTESTX10-9/91)

# AQUIFER PUMPING TEST DATA SHEET

DATE 5 \22\92 PERSON RECORDING DATA R Smith - EG&G

WELL # 6286 (881 HILLSIDE)
HYDROSTRATIGRAPHIC UNIT UPPER LARAMIE SANDSTONE
SCREENED INTERVAL 26.43 ft to 36 40 ft from TOC-SS

STATIC WATER LEVEL 26 41 ft @ TOC-SS PUMPING WELL I.D 2 in (CASING)

DISTANCE TO PUMPING WELL N/A ft WELL TD 36.85 ft @ TOC-SS
Pump INTAKE DEPTH 36 08 ft

TEST START TIME 09 18 50 INITIAL SATURATED THICKNESS 10 44 ft

| ELAPSED TIME (Units) (min) | Pump on/off | VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units) | ΔT (min) | AVERAGE Q (pumping well) (Units) (gpm) | WATER LEVEL |
|---|---|---|---|---|---|
| 0.0 | ON | | | | 26.41 |
| 2 0 | OFF | 2 3 | 2 0 | 1 15 | |
| 11 66 | ON | | | | |
| 13.58 | OFF | 0.55 | 11 58 | 0 047 | |
| 25.83 | ON | | | | |
| 26.32 | OFF | 0.5 | 12 74 | 0 039 | |
| 36.83 | ON | | | | |
| 38 58 | OFF | 0 | (Pump NOT PRIMING) | | |
| 38.74 | ON | | | | |
| 39.25 | OFF | 0 45 | 12 93 | 0 035 | |
| 51.17 | ON | | | | |
| 51 50 | OFF | 0 45 | 12 25 | 0 037 | |
| 63.67 | ON | | | | |

# AQUIFER PUMPING TEST DATA SHEET

DATE 5\22\92 PERSON RECORDING DATA ____________

WELL # 6286

HYDROSTRATIGRAPHIC UNIT ( See page 1)

SCREENED INTERVAL ______ ft to ______ ft

STATIC WATER LEVEL ______ ft PUMPING WELL I.D ______ in

DISTANCE TO PUMPING WELL ______ ft

TEST START TIME ______ ______ ______

| | ELAPSED TIME (Units) (min) | Pump on/off | ~~WATER LEVEL~~ VOLUME PUMPED (gals) (Units) | ΔT (min) | AVERAGE Q (pumping well) (Units) (gpm) | WATER LEV. (ft) |
|---|---|---|---|---|---|---|
| | 64.88 | off | 0 4 | 13 38 | 0 030 | |
| | 66.00 | on | | | | |
| | 77 12 ~~67 12~~ | off | 0 4 | 12 24 | 0 033 | |
| | 89.25 | on | | | | |
| | 89.83 | off | 0 35 | 12.71 | 0 028 | |
| | 101 33 | on | | | | |
| | 102 03 | off | 0 2 | 12 20 | 0.016 | |
| | 117.7 | on | | | | |
| | 118.10 | off | 0.45 | 16 07 | 0 028 | |
| END OF TEST | 132 66 | on | | | | |
| | 133.23 (0) | off | 0 4 | 15 13 | 0 026 | |
| | 135.08 (1 85) | | (RECOVERY | DATA) | | 35 51 |
| | 136.23 (3) | | | | | 35 25 |

# AQUIFER PUMPING TEST DATA SHEET

DATE 5/22/92 PERSON RECORDING DATA ____________

WELL # 6286

HYDROSTRATIGRAPHIC UNIT ____________ (see Page 1)

SCREENED INTERVAL ______ft to ______ft

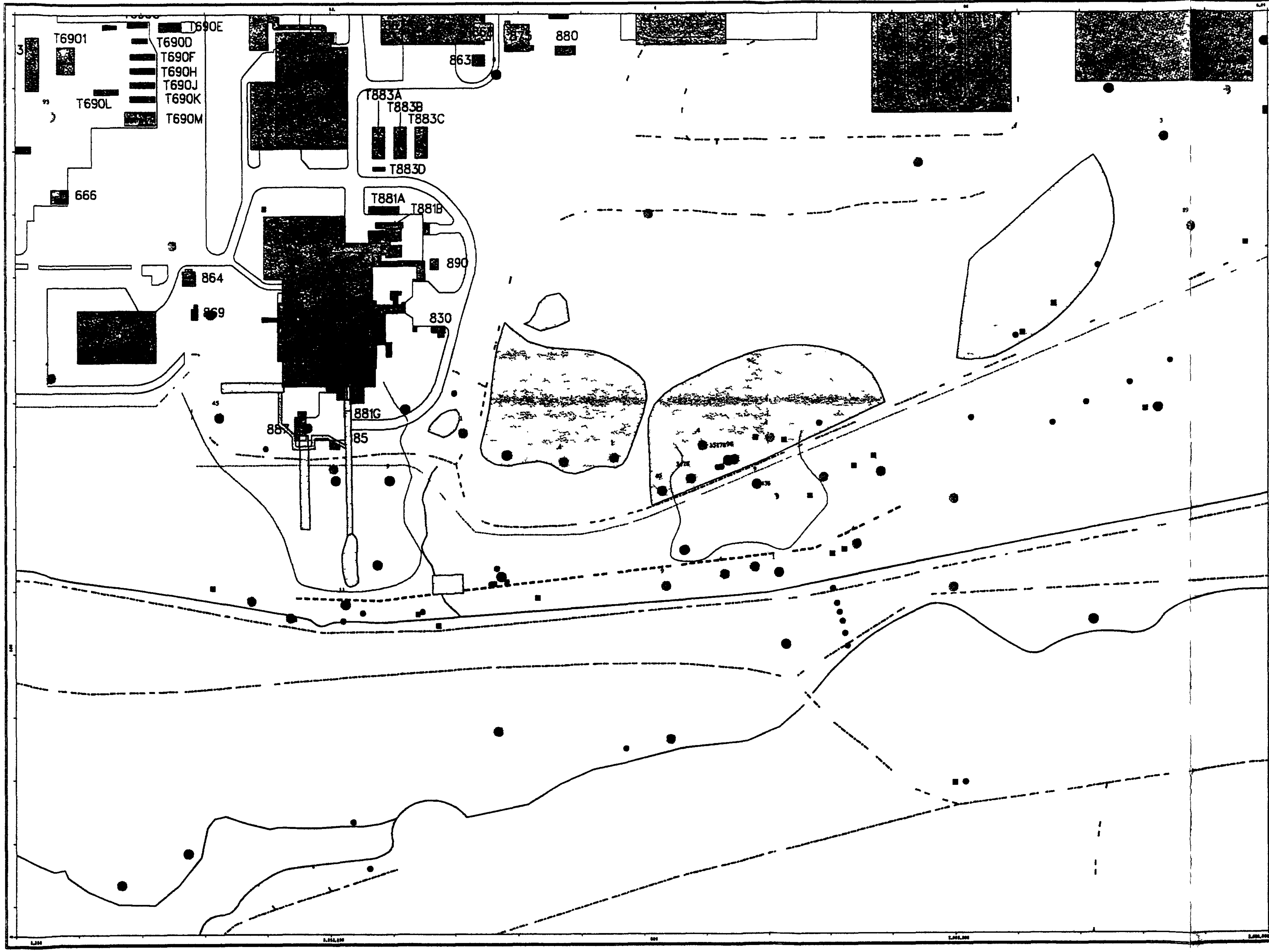
STATIC WATER LEVEL ______ft PUMPING WELL I.D ______in

DISTANCE TO PUMPING WELL ______ft

TEST START TIME ____ ____ ____

| ELAPSED TIME (Units) (min) | Pump on/off | VOLUME PUMPED (gals) ~~WATER LEVEL~~ (Units) | ΔT (mv) | AVERAGE Q (pumping well) (Units) (gpm) | WATER LEVEL |
|---|---|---|---|---|---|
| 137 23 (4) | | (RECOVERY | DATA) | | 35 02 |
| 138 23 (5) | | | | | 34 87 |
| 139 23 (6) | | | | | 34.72 |
| 140 23 (7) | | | | | 34.60 |
| 141.23 (8) | | | | | 34.49 |
| 142 23 (9) | | | | | 34.40 |
| 143 23 (10) | | | | | 34 31 |
| 144.23 (11) | | | | | 34.22 |
| 145 23 (12) | | | | | Probe Failure (unable to ~~desensitize~~ probe) |
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

(4011)(AQTEST)(10/29/91)




# Figure 1-4
# 881 Hillside Area
# Operable Unit 1
# Average Target Volatiles in Alluvial Groundwater
# all units = UG/L

**EXPLANATION**

- 0- 00
- 00- 000
- 000- 0000
- 0000
- LOCATION WITH NO DA
- BEDROCK LOCATION
- INDIVIDUAL HAZARDOUS SUBSTANCE SITE
- FRENCH DRAIN
- INFERRED EXTENT OF CONTAMINATION

**Standard Map Features**

- Buildings or other structures
- Lakes and ponds
- Streams, ditches, or other drainage features
- Fences
- Rocky Flats boundary
- Paved roads
- Dirt roads

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

U.S. Department of Energy
Rocky Flats Environmental Technology Site

Prepared by
EG&G ROCKY FLATS
Rocky Flats Environmental Technology Site
Box 464
Golden, Colorado 80402-0464

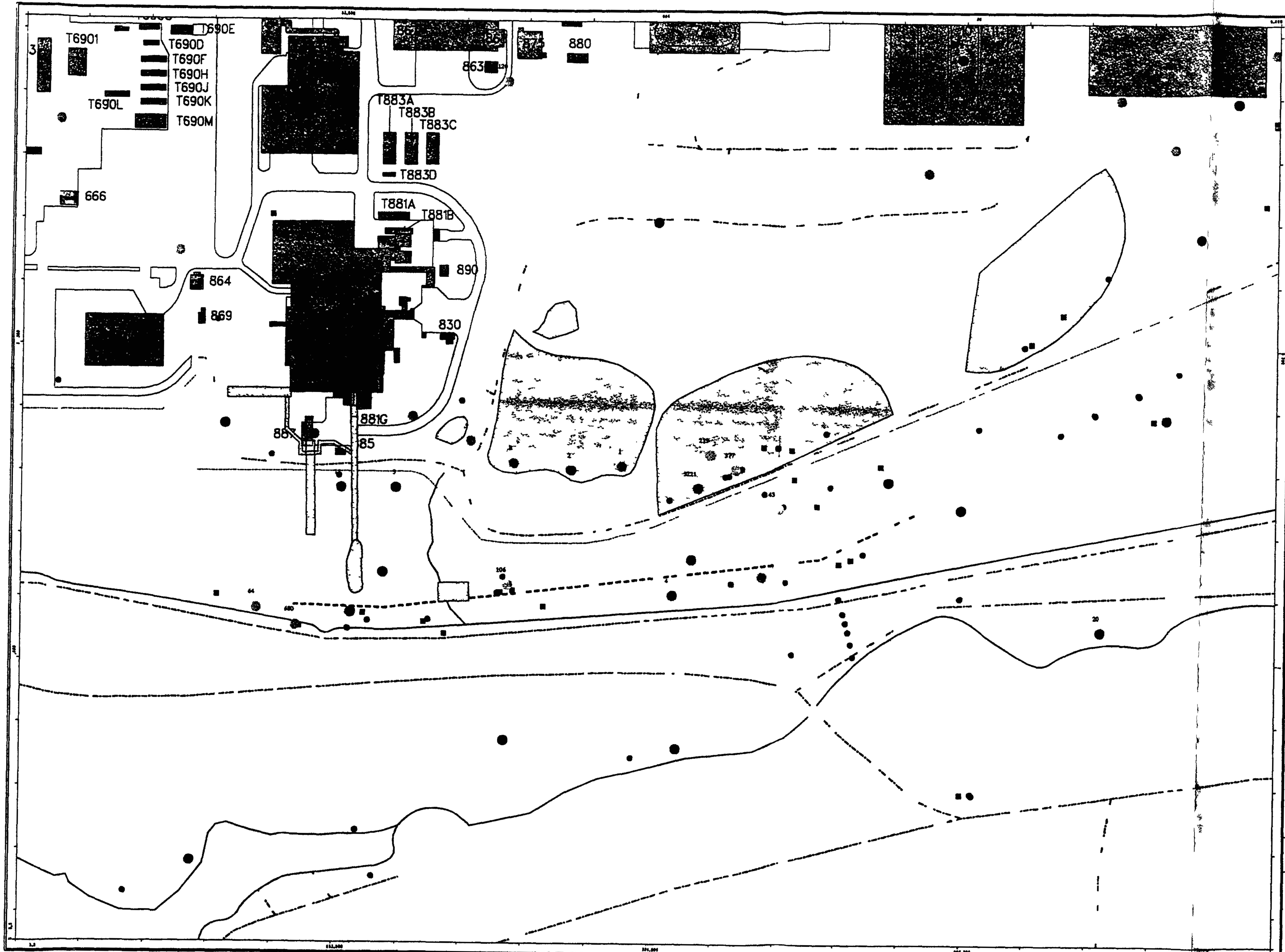



**Figure 1 5**
**881 Hillside Area**
**Operable Unit 1**
**Average Selenium Values**
**in Alluvial Groundwater**
**all units = UG/L**

EXPLANATION

0- 00
00- 000
000- 0000
0000
LOCATION WITH NO DAT
BEDROCK LOCATION
INDIVIDUAL HAZARDOUS SUBSTANCE SITE
FRENCH DRAIN

Standard Map Features

Buildings or other structures
Lakes and ponds
Streams, ditches, or other drainage features
Fences
Rocky Flats boundary
Paved roads
Dirt roads

Scale 2650
1 inch represents approximately 220.83 feet

State Plane Coordinate Projection
Colorado Central Zone
Datum NAD27

U S Department of Energy
Rocky Flats Environmental Technology Site

Prepared by
EG&G ROCKY FLATS
Rocky Flats Environmental Technology Site
Box 464
Golden, Colorado 80402-0464

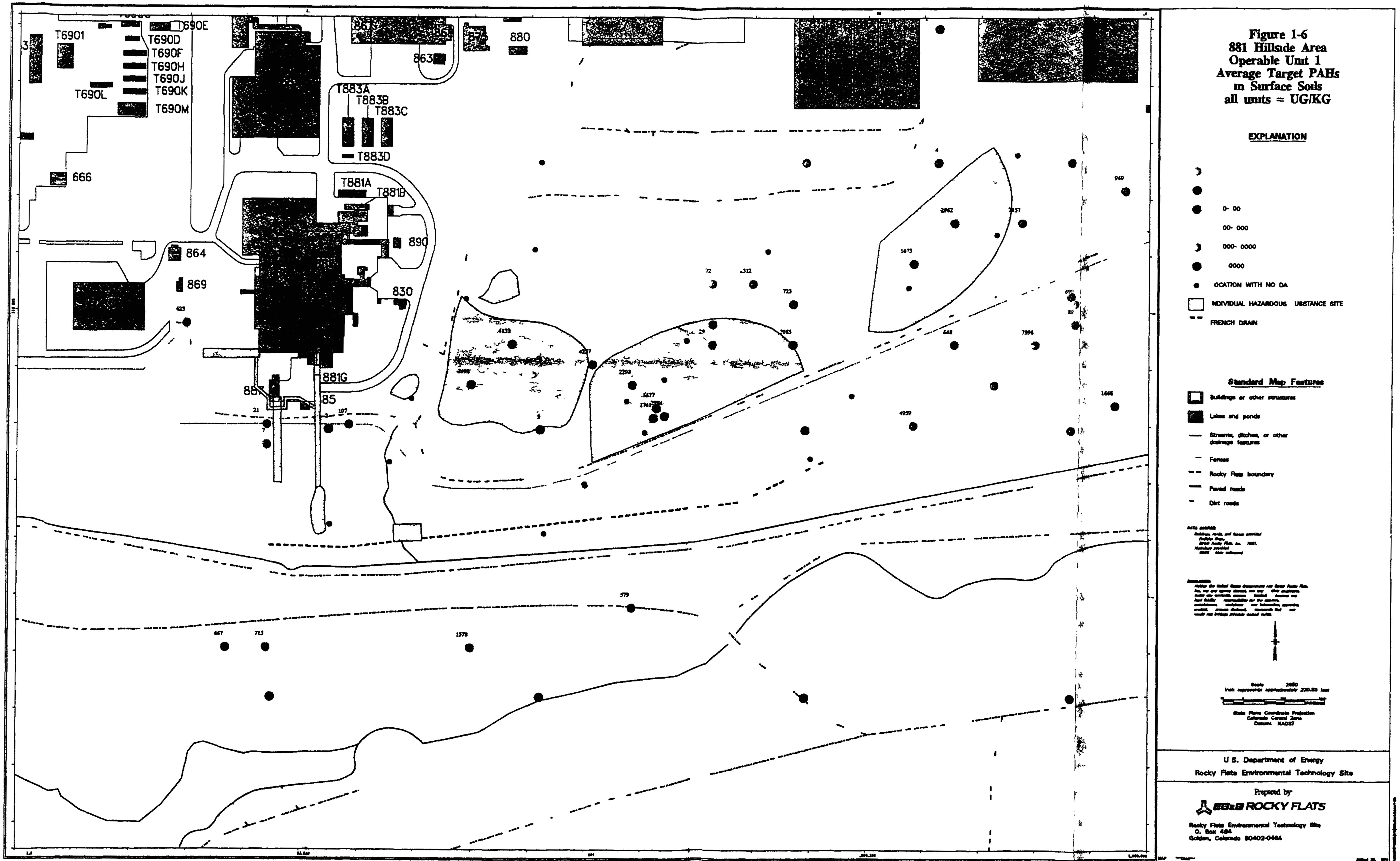



Figure 1-6
881 Hillside Area
Operable Unit 1
Average Target PAHs
in Surface Soils
all units = UG/KG

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Golden, Colorado 80402-0464

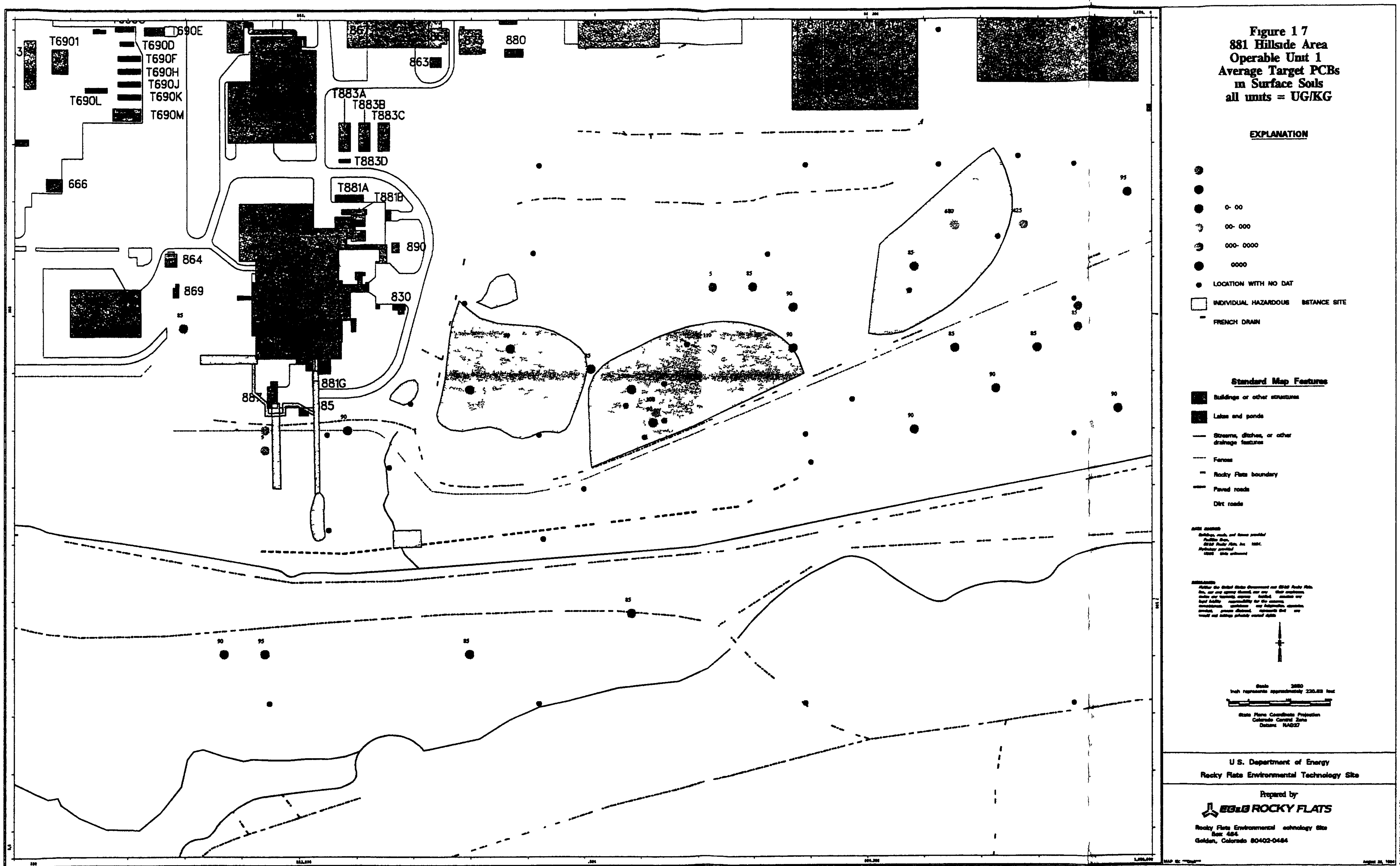
Figure 1 7
881 Hillside Area
Operable Unit 1
Average Target PCBs
in Surface Soils
all units = UG/KG
EXPLANATION
0- 00
00- 000
000- 0000
0000
LOCATION WITH NO DAT
INDIVIDUAL HAZARDOUS BSTANCE SITE
FRENCH DRAIN
Standard Map Features
Buildings or other structures
Lakes and ponds
Streams, ditches, or other drainage features
Fences
Rocky Flats boundary
Paved roads
Dirt roads
State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27
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Rocky Flats Environmental echnology Site
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Golden, Colorado 80402-0464
T6901
T690D
T690E
T690F
T690H
T690J
T690K
T690L
T690M
666
864
869
867
863
880
T883A
T883B
T883C
T883D
T881A
T881B
890
830
881G
887
85

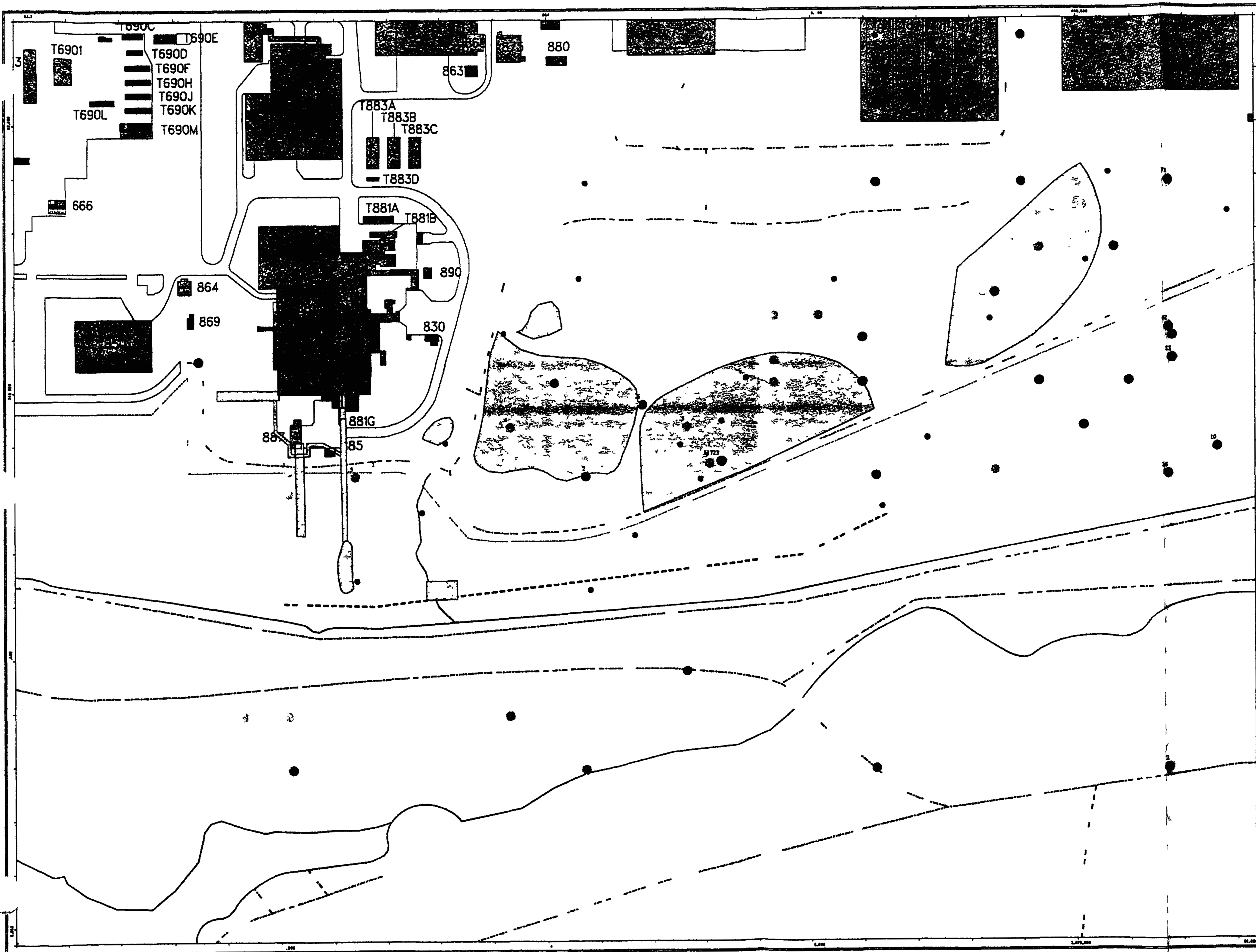


**Figure 1-8**
**881 Hillside Area**
**Operable Unit 1**
**Average Pu 239/240**
**in Surface Soils**
**all units = PCI/G**

EXPLANATION

- < 1
- 1 1
- 1 10
- 10-100
- 100-1000
- 1000-10000
- 10000
- LOCATION WITH NO DATA
- INDIVIDUAL HAZARDOUS SUBSTANCE SITE
- FRENCH DRAIN

Standard Map Features

- Buildings or other structures
- Lakes and ponds
- Streams, ditches, r other drainage features
- Fences
- Rocky Flats boundary
- Paved roads
- Dirt oads

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

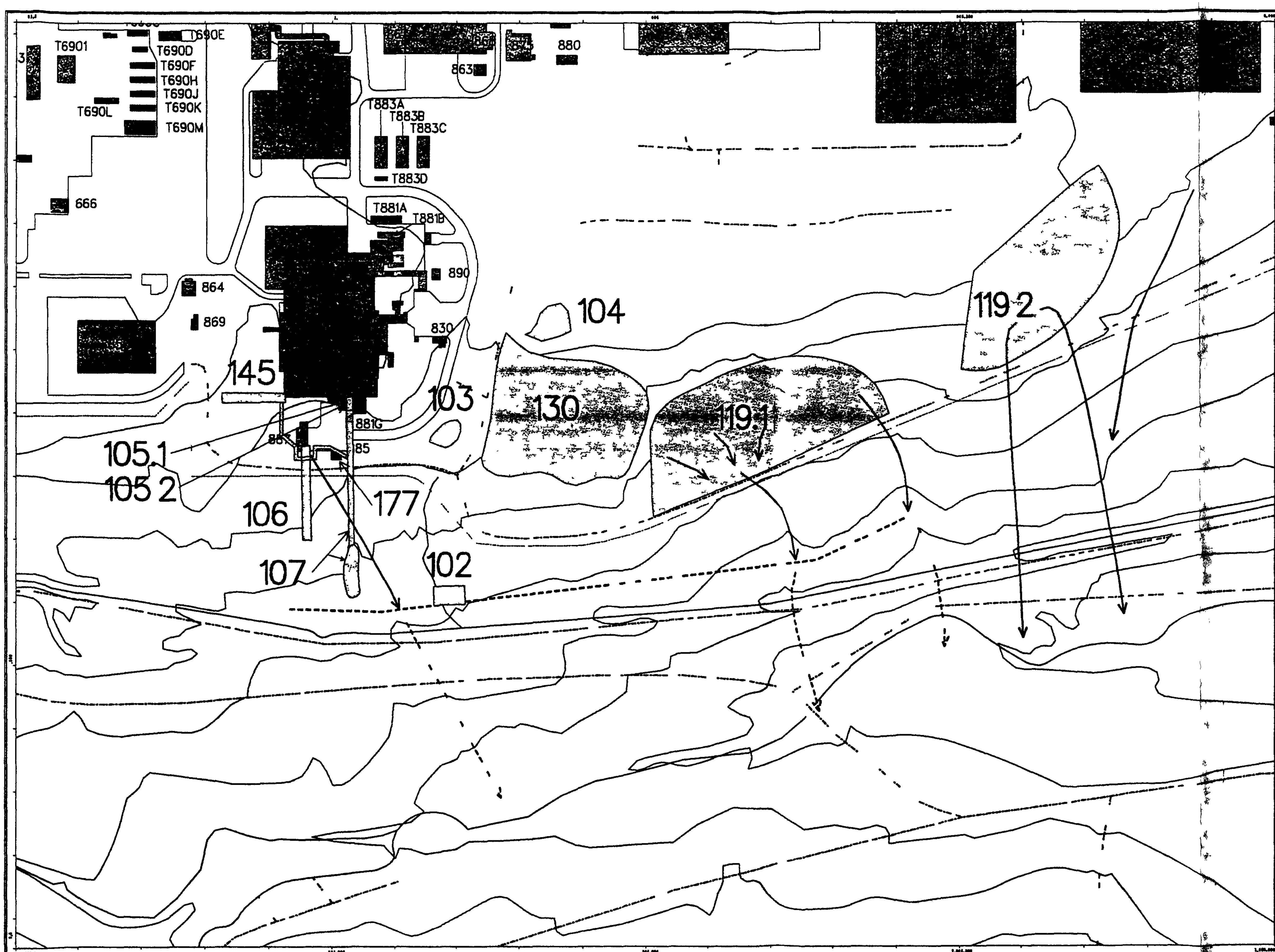


**Figure 1 9**
**881 Hillside Area**
**Operable Unit 1**
**IHSS Locations**
**Potential Groundwater**
**Migration Pathways**

EXPLANATION

INDIVIDUAL HAZARDOUS SUBSTANCE SITE
FRENCH DRAIN
ACTIVE W PATHWAYS
PRE-FRENC RAIN THW

Standard Map Features

Buildings or other structures
Lakes and ponds
Streams, ditches, or other drainage features
Fences
Contours (20' Intervals)
Rocky Flats boundary
Paved roads
Dirt roads

State Plane Coordinate Projection
Colorado Central Zone
Datum: NAD27

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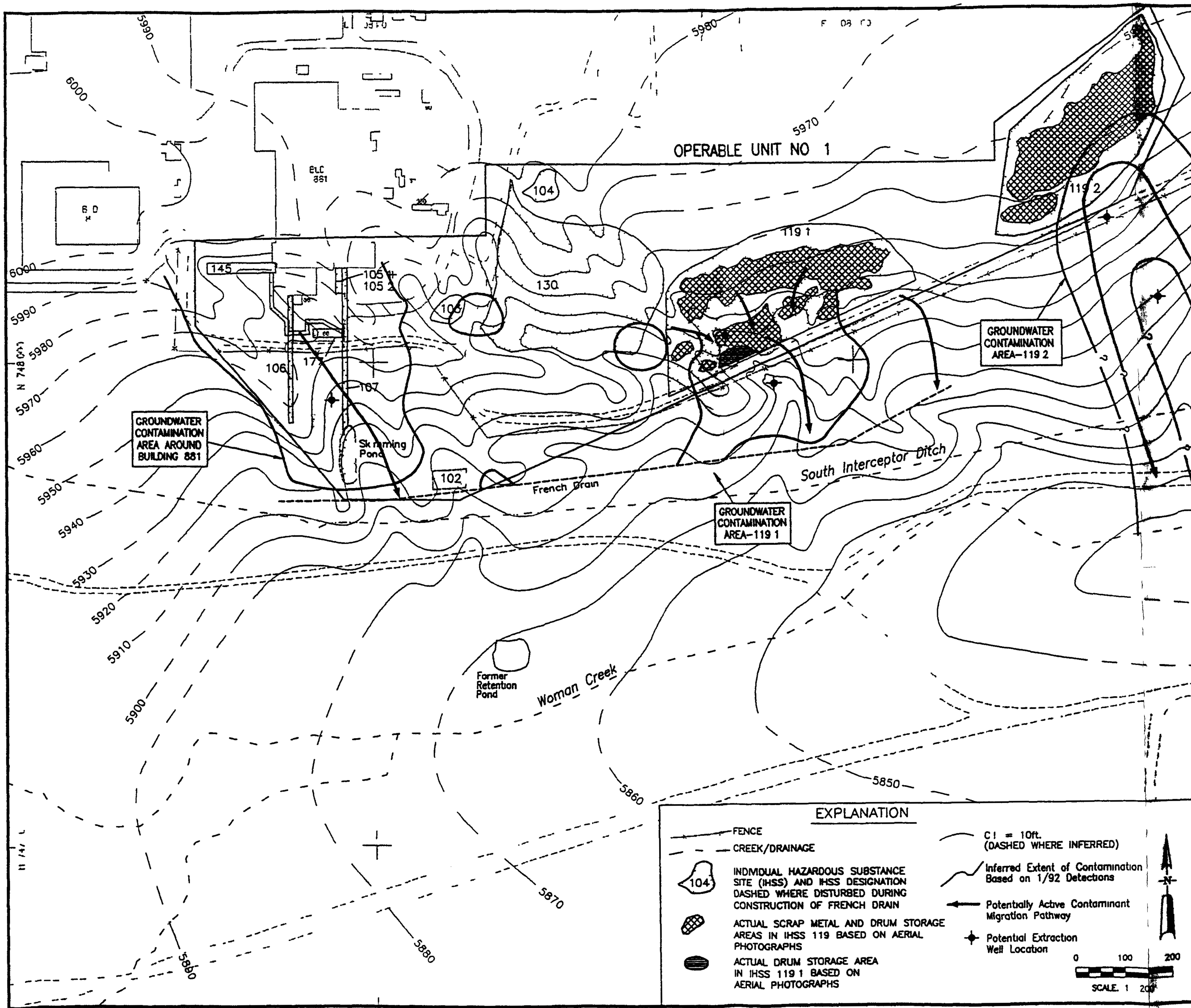
Golden, Colorado 80402-0464

Table 3-1
Summary of Groundwater Remedial Action Alternative Development[a]

| GENERAL RESPONSE ACTION | PROCESS OPTION | PROPOSED REMEDIAL ACTION ALTERNATIVES | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | | No Action | Institutional Controls without the French Drain | Institutional Controls with the French Drain | Modified French Drain with Additional Extraction Wells | Groundwater Pumping and Soil Vapor Extraction | Groundwater Pumping and SVE with Thermal Enhancement | Hot Air Injection with Mechanical Mixing | Groundwater Removal by Soil Excavation and Sump Pumps | [illegible] |
| AREA ADDRESSED => | | N/A | All IHSSs | All IHSSs | All IHSSs | IHSS 119 1 | IHSS 119 1 | IHSS 119 1 | IHSS 119 1 | [illegible] |
| No action | Groundwater monitoring | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| Institutional controls | Legal restrictions on land use | | ✓ | ✓ | ✓ | | | | | ✓ |
| | Legal restrictions on well placement | | ✓ | ✓ | ✓ | | | | | ✓ |
| Containment | Subsurface drains (existing French Drain) | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Environmental isolation enclosure (optional) | | | | | | | | ✓ | |
| | Surface cap | | | | | | | | | ✓ |
| Removal | Subsurface drains (existing French Drain) | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| | Horizontal and/or vertical extraction wells or sumps | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | |
| | Loader/dozer/excavator | | | | | | | | ✓ | |
| In situ treatment of chlorinated solvents | RF/ohmic heating | | | | | | ✓ | | | |
| | Soil vapor extraction | | | | | ✓ | ✓ | | | |
| | Hot air/steam stripping with mechanical mixing | | | | | | | ✓ | | |
| Ex situ treatment of chlorinated solvents | Ultraviolet photolysis with chemical oxidation | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |
| Ex situ treatment of inorganics | Ion exchange | | | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ |

[a] Shaded alternatives were screened from further consideration on the basis of effectiveness implementability or cost

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Golden Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1

Potential Locations for Additional Extraction Wells

Figure 3-1

# Table 4-1
## Summary of Detailed Analysis of Alternatives

| CERCLA Analysis Criteria | [illegible] No Action | [illegible] Controls Without the French Drain | [illegible] Controls With the French Drain | [illegible] Modified French [illegible] With Additional Extraction Wells | [illegible] Groundwater Pumping and [illegible] | [illegible] and Soil [illegible] Extraction With [illegible] | [illegible] Hot Air [illegible] Mechanical Mixing | [illegible] |
|---|---|---|---|---|---|---|---|---|
| **Overall Protectiveness** | | | | | | | | |
| Human Health Protection | Human health risk fo receptors at Woman Creek would be and 1 99x10$^{-4}$ Risk from soils would be within acceptable rang of 10$^{-4}$ to 10$^{-6}$ | Human health would be ffectively protected because access to OU 1 would be controlled | Risk would be reduced slightly compared to No Action alternati Risk lev l for a receptors at Woman Creek would be 4 76x10 Risk from surface soils would be within acceptable range of 10$^{-4}$ to 10$^{-6}$ | Human health risk would be reduced compared to Alternati e 2 although ot significantly Risk from surface soils would be within acceptable rang f 10$^{-4}$ to 10$^{-6}$ | Human health risk for receptors at Woman Creek would be 3 22x10 Risk from surface soils would be within acceptable range f 10$^{-4}$ to 10$^{-6}$ | Human health risk f receptors at Woman C eek would be 3 22x10 Risk from surface soils w uld be within acceptabl range of 10$^{-4}$ to 10$^{-6}$ | Human health risk f r receptors at W man Creek would be 3 22x10 Risk from surface soils would be within acceptable rang of 10$^{-4}$ to 10$^{-6}$ | Human health risk for receptors at the Woman would be 3 22x10 Risk from surface soils would be within acceptable range of 10$^{-4}$ to 10$^{-6}$ |
| Environme tal Protection | Transport modeling indicates that MCLs would continue to be met at Woman Creek. | Transport modeling indicates that MCLs would continue to be met at Woman Creek | Transport modeling indicates that MCLs would continue to be met at Woman Creek. | Transport modeling indicates that MCLs would continue to be met at Woman Creek | No environmental impacts are anticipated Transport modeling indicates that MCLs would continue to be met at Woman Creek | RF heating may ha adverse effects on subsurface Transport modeling indicates that MCLs would contin e to be met at Woman Creek. | Hot air injection and mechanical mixing may have adverse effects on the subsurface Transport modeling indicates that MCLs would continue to be met at Woman Creek | Large exca ation and material transportation requirements may significantly impact environment. Transport modeling indicates that MCLs would continue to be met at Woman Creek |
| **Compliance With ARARs** | | | | | | | | |
| Ability to Meet ARARs | Key ARARs would be met | Key ARARs would be met. | Key ARARs would be met. | Key ARARs would be met. | Key ARARs would be met. | Key ARARs would be met | Key ARARs would be met. | Key ARARs would be met. |
| **Long-Term Effectiveness and Permanence** | | | | | | | | |
| Magnitude of Residual Risk | No significant chang from existing risk. | Residual risk reduced because ature RFETS would be controlled | No significant change from existing risk. | No significant change from existing risk. | Residual risk would be reduced through reduction of COCs vailable for further migration Residual risk would be slightly less than for Alternati e 3 due to removal of COC source | Residual risk would be reduced through red ction of COCs availabl f further migration Residual risk would be slightly less than the institutional control alternati es due to removal of COC source | Residual risk would be reduced through reduction of COCs vailable f further migration Residual risk would be slightly less than the institutional control alternatives due to removal of COC source | Residual risk would be reduced through reduction of COCs available for further migration Residual risk would be slightly less than the institutional control alternatives due to removal of COC source |
| Adequacy and Reliability of Controls | No controls would be used to protect human health or the environment. | Institutional controls will effectively protect human health No controls would be used to protect the environment, although no significant impacts are identified | Institutional controls would effectively protect human health. French drain would continue to prevent COC migration beyond OU 1 | Institutional controls would effectively protect human health French drain and additional extraction wells would continue to prevent COC migration beyond OU 1 | Contaminants would be controlled through source removal However COC residuals may reduce effectiveness of long term control | Contaminants would be controlled through source removal Howe COC residuals may reduce effectiveness of long term control Control would be lightly more effecti than for Alternative 4 because source remo al would be more effecti | Contaminants would be controlled through source removal However COC residuals may reduce effectiveness of long term control Control may be slightly more effective than for Alternative 5 because source removal may be more effectiv | Contaminants would be controlled through source removal Controls should be significantly more effecti than those unde other remedial alternati es because ture source area would be exca ated |
| Need for 5 Year Review | Five-year review would be conducted | Five-year review would be conducted | Five-year review would be conducted | Five-year review would be conducted. | Five-year review would be conducted. | F ve-year review would be conducted. | Five-year review would be conducted. | Five-year review would be conducted. |

Table 4 1
(Continued)

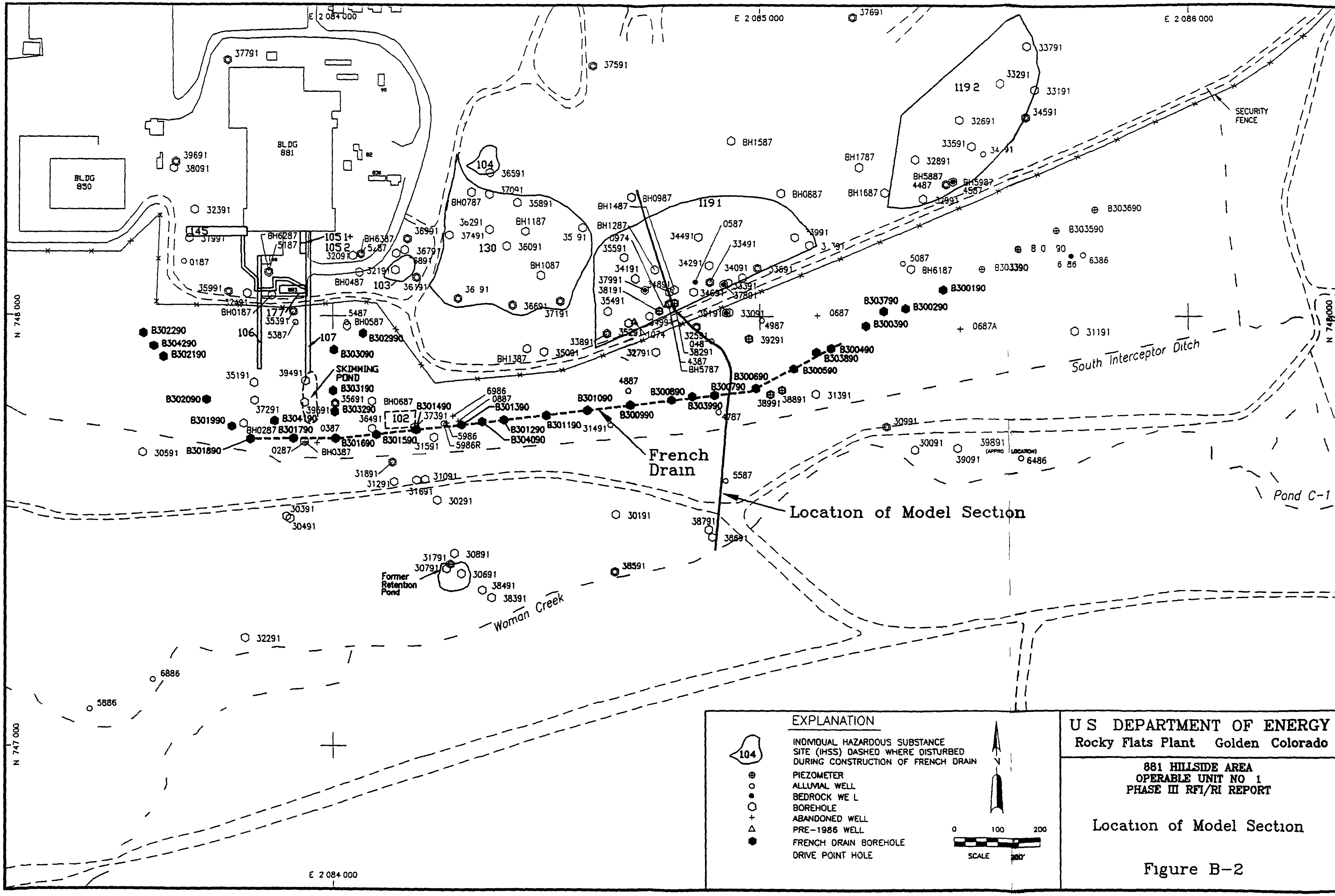
| CERCLA Analysis Criteria | ALTERNATIVE 0 No Action | ALTERNATIVE 1 Institutional Controls Without the French Drain | ALTERNATIVE 2 Institutional Controls With the French Drain | ALTERNATIVE 3 Modified French Drain With Additional Extraction Wells | ALTERNATIVE 4 Groundwater Pumping and Soil Vapor Extraction | ALTERNATIVE 5 Groundwater Pumping and Soil Vapor Extraction With RF Enhancement | ALTERNATIVE 6 Hot Air Injection With Mechanical Mixing | ALTERNATIVE 7 Soil Excavation and Groundwater Removal With ... Pumps |
|---|---|---|---|---|---|---|---|---|
| **Reduction of Toxicity Mobility or Volume Through Treatment** | | | | | | | | |
| Treatment Process Used | None | None | Extracted groundwater would be treated by existing Building 891 UV/peroxide/ion exchange process | Extracted groundwater would be treated by existing Building 891 UV/peroxide/ion exchange process | SVE is a proven techn logy Recovered soil gas would be treated with acti ated carbon Extracted groundwater would be treated by existing Building 891 UV/peroxide/ion exchange process | RF heating as an SVE nhancement is an innovative technology Recovered soil gas w uld be treated with acti ated carbon Extracted groundwater would be treated by existing Building 891 UV/ peroxide/ion exchang process | Hot air injection with in situ mechanical mixing is an innovati e techn logy Recovered soil gas would be treated with acti ated carbon Extracted groundwate would be treated by existing Building 891 UV/peroxide/ion exchange process | Excavated soil would be treated with thermal desorption Off gas would be treated by catalytic oxidation Extracted groundwater would be treated by existing Building 891 UV/peroxide/ion exchang process |
| Amount Destroyed or Treated | None | None | Small quantities of COCs would be treated due to low concentrations in groundwater and low extraction rate | Small quantities of COCs would be treated due to low concentrations in groundwater and low extraction rate | SVE may not effectively remove COCs due to low permeability of soils | Greater quantity of COCs may be removed and treated than for Alternative 4 due to RF heating | Greater quantity of COCs may be removed than for Alternatives 4 and 5 due to hot air injection and mechanical mixing | All COCs in treatment zone would be removed by excavation and subsequent soil treatment |
| Reduction of Toxicity Mobility or Volume | None | None | French drain would continue to reduce mobility and volume of COCs Toxicity would be reduced through UV/peroxide/ion exchange process | French drain and additional extraction wells would reduce mobility and volume of COCs Toxicity would be reduced through UV/peroxide/ion exchange process | SVE would effectively reduce volume and mobility of COCs Toxicity would be reduced through carbon regeneration process and UV/peroxide/ion exchange process | Reduction of volume and mobility and toxicity may be slightly more eff ctive than for Alternati 4 due to RF heating | Reduction of volume and mobility and toxicity may be slightly more effecti than for Alternatives 4 and 5 due to hot air injection and mechanical mixing | Excavation would provide the most effective reduction of COC olume and mobility Toxicity would be reduced through off gas treatment and the existing UV/peroxide/ion exchange process |
| Irreversible Treatment | Not Applicable | Not Applicable | Contaminant removal would be irreversible However DNAPLs may continue to act as source | Contaminant removal would be irreversible However DNAPLs may continue to act as source | Contaminant removal would be irreversible However DNAPLs may continue to act as source | Contaminant removal would be irreversibl However DNAPLs may continue to act as source. | Contaminant removal would be irreversible However DNAPLs may continue to act as source | Contaminant removal would be irreversible assuming all DNAPL sources are removed |
| Type and Quantity of Residuals Remaining after Treatment | Existing contaminant concentrations would remain unchanged | Existing contaminant concentrations would remain unchanged | Continued operation of the french drain would further reduce volume of contaminants Residual concentrations of COCs would remain in subsurface soils and groundwater | Operation of french drain and additional extraction wells would further reduce volume of contaminants Residual concentrations of COCs would remain in subsurface soils and groundwater | Residual concentrations of COCs may remain at IHSS 119 1 following treatment. Low concentrations of COCs would remain in downgradient groundwater | Residual conce trations of COCs may remain at IHSS 119 1 following treatment. Low concentrations of COCs would remain in downgradient groundwater | Residual concentrations of COCs may remain at IHSS 119 1 following treatment. Low concentrations of COCs would remain in downgradient groundwater | No residual concentrations of COCs would remain at IHSS 119 1 following excavation Low concentrations of COCs would remain in downgradient groundwater |
| Statutory Pref rence for Treatment | Does not satisfy preference f r treatment. | Does not satisfy preference for treatment. | Satisfies preference for treatment | Satisfies preference for treatment. | Satisfies preference for treatment | Satisfies prefere ce fo treatment. | Satisfies preference f treatment | Satisfies preference for treatment. |

Table 4-1
(Continued)

| CERCLA Analysis Criteria | ALTERNATIVE No Action | ALTERNATIVE Institutional Controls Without the French Drain | ALTERNATIVE Institutional Controls With the French Drain | ALTERNATIVE 3 Modified French Drain With Additional Extraction Wells | ALTERNATIVE 4 Groundwater Pumping and Soil Vapor Extraction | ALTERNATIVE Groundwater Pumping and Soil Vapor Extraction With Enhancement | ALTERNATIVE 6 Ex Situ Injection With Mechanical Mixing | ALTERNATIVE Soil Excavation and Groundwater Removal With Pumps |
|---|---|---|---|---|---|---|---|---|
| **Short Term Effectiveness** | | | | | | | | |
| Community Protection | No increase in potential risks to the public | Reduces potential risks to public by restricting site access | No increase in potential risks to the public | No increase in potential risks to the public | No significant increase in potential risks to the public | No significant increas potential risks to the public | No significant increase in potential risks to the public | Potential risks to public due to air borne dust generated during excavation activities and transport of excavated soil off site |
| Worker Protection | No increase in potential risks to workers | No increase in potential risks to workers | No increase in potential risks to workers | No increase in potential risks to workers | Potential risks from exposure to COCs in groundwater or soil vapor and safety hazards associated with drilling and construction Risks would be minimized through standard health and safety practices | Potential risks from exposure to COCs in groundwater or soil vapor and safety hazards associated with drilling and construction Risks would be minimized through standard health and safety practices | Potential risks from exposure to COCs in groundwater or soil vapor and safety hazards associated with operating specialized equipment. Risks would be minimized through standard health and safety practices | Potential risks from exposure to COCs in groundwater or air-borne dust and safety hazards associated with excavating equipment. Risks would be minimized through standard health and safety practices |
| Environmental Impacts | No additional environmental impacts | No additional environmental impacts | No additional environmental impacts | No additional environmental impacts | Minor impacts to soil including limited loss of egetation | Minor loss of egetation associated with construction activities situ heating may ha significant impact on subsurface | Significant impact on environment due to rigorous soil mixing and in situ heating In addition soil stability problems at OU 1 would be exacerbated by the process | Exca ation would have significant short term impacts on environment |
| Time Until Response Objectives are Achieved | Groundwater would continue to meet MCLs at Woman Creek. | Groundwater would continue to meet MCLs at Woman Creek. | Groundwater would continue to meet MCLs at Woman Creek | Groundwater would continue to meet MCLs at Woman Creek. | SVE would remove source in 5 years Groundwater would continue to meet MCLs at Woman Creek | Enhanced SVE would remove source in 3 years Groundwater would continue to meet MCLs at Woman Creek. | Source would be removed in less than 1 year Groundwater would continue to meet MCLs at Woman Creek. | Source would be removed and soil treated in less than 1 year Groundwater would continue to meet MCLs at Woman Creek |
| **Implementability** | | | | | | | | |
| Ability to Construct and Operate | Not Applicable | Not Applicable | Would only include operation of existing equipment. | Simple to construct and operate new wells using conventional readily a ailable technology | Simple to construct using conventional readily vailable technology | Simple to construct and operate using conventional readily available technology | Simple to implement using readily available technology However soil stability concerns may limit operation of mixing device | Excavation can be implemented using standard earth-moving equipment and dewatering pumps However potential radionuclide contamination in subsurface soils may limit ability to transfer soils off site |
| Ease of Doing More Action if Needed | Would not limit the ability to perform future remedial actions | Would not limit the ability to perform future remedial actions | Would not limit the ability to perform future remedial actions | Would not limit the ability to perform future remedial actions | Would not limit the ability to perform future remedial actions | Would not limit the ability to perform future remedial actions | Would not limit the ability to perform future remedial actions | Would not limit the ability to perform future remedial actions |
| Ability to Monitor Effectiveness | Existing monitoring programs would track movement of COCs | Existing monitoring programs would track movement of COCs | Existing monitoring programs would track movement of COCs | Existing monitoring programs would continue to track movement of COCs | Existing monitoring programs would determine effectiveness | Existing monitoring programs would determine effectiveness | Existing monitoring programs would determine effectiveness | Existing monitoring programs would determine effectiveness |

Table 4-1
(Continued)

| CERCLA Analysis Criteria | ALTERNATIVE 0 No Action | ALTERNATIVE 1 Institutional Controls Without the French Drain | ALTERNATIVE 2 Institutional Control With the French Drain | ALTERNATIVE 3 Modified French Drain With Additional Extraction Wells | ALTERNATIVE 4 Groundwater Pumping and Soil Vapor Extraction | ALTERNATIVE 5 Groundwater Pumping and Soil Vapor Extraction With Thermal Enhancement | ALTERNATIVE 6 Hot Air Injection With Mechanical Mixing | ALTERNATIVE 7 Soil Excavation and Groundwater Removal With Sump Pumps |
|---|---|---|---|---|---|---|---|---|
| Ability to Obtain Permits/Coordination with Agencies | No problems anticipated | No problems anticipated | No problems anticipated | No problems anticipated | No problems anticipated | No problems anticipated | No problems anticipated | Potential radionuclide contamination in subsurface soils may limit ability to transfer soils off site |
| Availability of Services and Capacities | No services required | No services required | No additional services required | Services readily available | Services readily available | Services readily available | Services readily available | Services readily available |
| Availability of Equipment, Specialists, and Materials | None required | None required | None required | Readily available | Readily available | Readily available | Likely to be readily available although technology is considered innovative | Readily available |
| Availability of Technologies | None required | None required | None required | Readily available; would utilize common construction techniques | Readily available | Readily available | Likely to be readily available although technology is considered innovative | Readily available; would utilize common construction techniques |
| **Cost** | | | | | | | | |
| Present Worth (1994) Cost | $1 895 100 | $1 895 100 | $17 493 300 | $17 648 700 | $8 141 800 | $7,503 100 | $5 030 800 | $13 093 700 |




U S DEPARTMENT OF ENERGY
Rocky Flats Plant Golden Colorado

881 HILLSIDE AREA
OPERABLE UNIT NO 1
PHASE III RFI/RI REPORT

Location of Model Section

Figure B-2

Table D 1
Potential Federal
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

| Standard Requirement Criteria or Limitation | Citation | [illegible] No Action | 1 Institutional Controls without the French Drain | [illegible] Institutional Controls with the French Drain | 3 Modified French Drain with Additional Extraction Wells | [illegible] Groundwater Pumping and Soil Vapor Extraction | [illegible] Groundwater Pumping and SVE with Thermal Enhancement | 6 Steam Injection with Mechanical Mixing | [illegible] Soil Excavation and Groundwater Removal with Sump Pumps |
|---|---|---|---|---|---|---|---|---|---|
| Resource Conservation and Recovery Act (RCRA) | 42 USC Secs 6901 6987 | | | | | | | | |
| A Criteria for Classification of Solid Waste Disposal Facilities and Practices | 40 CFR Part 257 | NA | NA | NA | NA | $A^2$ | $A^2$ | $A^2$ | $A^2$ |
| B Hazardous Waste Management Systems General | 40 CFR Part 260 | R/Y | R/Y | R/Y | R/Y | $A^2$/Y | $A^2$/Y | $A^2$/Y | $A^2$/Y |
| C Identification and Listing of Hazardous Wastes | 40 CFR Part 261 | R/Y | R/Y | R/Y | R/Y | $A^2$/Y | $A^2$/Y | $A^2$/Y | $A^2$/Y |
| D Proposed Definition of Hazardous Waste to Exclude Environmental Media[1] 58FR48156 | 40 CFR Part 260 261 261 4 261 42 and 268 | C/Y[1] | C/Y[1] | C/Y[1] | C/Y[1] | C/Y[1] | C/Y[1] | C/Y[1] | C/Y[1] |
| E Standards Applicable to Generators of Hazardous Waste | 40 CFR Part 262 | R/Y | R/Y | R/Y | R/Y | $A^2$/Y | $A^2$/Y | $A^2$/Y | $A^2$/Y |
| F Releases from Solid Waste Management Units | 40 CFR Part 264 Subpart F | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y |
| G Closure and Post Closure | 40 CFR Part 264 112 Subpart G and 264 601 | R/Y | R/Y | R/Y | R/Y | A/Y | A/Y | A/Y | A/Y |
| H Use and Management of Containers | 40 CFR Part 264 Subpart I | NA | NA | NA | NA | A/Y | A/Y | A/Y | A/Y |
| I Landfills | 40 CFR Part 264 Subpart N | NA | NA | NA | NA | NA | NA | NA | NA |
| J Miscellaneous Units | 40 CFR Part 264 Subpart X | NA | NA | NA | NA | R/Y | R/Y | R/Y | R/Y |
| K Air Emission Standards for Process Vents | 40 CFR Part 264 1032 and 264 1033 Subpart AA | NA | NA | NA | NA | A/Y | A/Y | A/Y | A/Y |
| L Air Emission Standards for Equipment Leaks | 40 CFR Part 264 1056 1057 Subpart BB | NA | NA | NA | NA | A/Y | A/Y | A/Y | A/Y |
| M Proposed Air Emission Standards for Storage Units | 40 CFR Part 264 1083 Subpart CC | NA | NA | NA | NA | C/Y[3] | C/Y[3] | C/Y[3] | C/Y[3] |
| N Temporary Unit | 40 CFR Part 264 553 Subpart S | NA | NA | NA | NA | A/Y | A/Y | A/Y | A/Y |

Assumes requirements of 261 42 could be met, acceptable risk range $10^{-4}$ $10^{-6}$ and levels in soil and groundwater do not pose human health hazard nor environmental hazard
2 Applies to new treatment system
3 May apply if concentration of organics in tank exceed 500 ppmv

**Table D 1**
**Potential Federal**
**Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives**

| Standard Requirement Criteria or Limitation | Citation | 0<br>No Action | 1<br>Institutional Controls without the French Drain | 2<br>Institutional Controls with the French Drain | 3<br>Modified French Drain with Additional Extraction Wells | 4<br>Groundw[illegible]er Pumpi[illegible]d Soil V[illegible] Extrac[illegible] | 5<br>Groundwater Pumping and SVE with Thermal Enhancement | 6<br>Steam Injection with Mechanical Mixing | 7<br>Soil Excavation and Groundwater Removal with Sump Pumps |
|---|---|---|---|---|---|---|---|---|---|
| O Corrective Action for Solid Waste Management Unit (CAMU) | 40 CFR 264 552 Subpart S | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y |
| P Interim Status Standards for Owners and Operators of Hazardous Waste Treatment Storage and Disposal Facilities | 40 CFR Part 265 | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y |
| Q Interim Status Standards for Owners and Operators of New Hazardous Waste Land Disposal Facilities | 40 CFR Part 267 | NA | NA | NA | NA | NA | NA | NA | NA |
| R Land Disposal Restrictions | 40 CFR Part 268 | NA | NA | NA | NA | A[4]/Y | A[4]/Y | A[4]/Y | A[4]/Y |
| **Toxic Substances Control Act** | 15 USC Secs 2601 2629 | | | | | | | | |
| A PCB Requirements | 40 CFR Part 761 | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y |
| **Clean Water Act** | 33 USC Secs 1251 1376 | | | | | | | | |
| A Discharge of Effluent<br>FF CA CWA 90-1 NPDES Federal Facility Compliance Agreement | 40 CFR Sec 125 100<br>40 CFR Sec 122 41 | A/Y | NA | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y |
| B Toxic Pollutant Effluent Standards | 40 CFR 129 | NA | NA | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y |
| C Discharge of Stormwater | 40 CFR Sec 122 21<br>40 CFR Sec 122 26 | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y |
| **Atomic Energy Act** | 42 USC Secs 2011 et seq | | | | | | | | |
| A Radiation Protection and Radioactive Waste Management | 10 CFR Part 20 1301 20 1302 Subpart D and K | NA | NA | NA | NA | NA | NA | NA | A/Y |
| B Performance Objectives in Licensing for Land Disposal of Radioactive Waste | 10 CFR Part 61 | C[5]/Y | C[5]/Y | C[5]/Y | C[5]/Y | C[5]/Y | C[5]/Y | C[5]/Y | C[5]/Y |

4 Applies to residuals of treatment system such as spent carbon, HEPA filters or ion exchange resins
5 Considered for impacts to groundwater

Table D 1
Potential Federal
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

| Standard Requirement Criteria or Limitation | Citation | 0<br>No Action | 1<br>Institutional Controls without the French Drain | 2<br>Institutional Controls with the French Drain | 3<br>Modified French Drain with Additional Extraction Wells | 4<br>Groundwater Pumping and Soil Vapor Extraction | 5<br>Groundwater Pumping and SVE with Thermal Enhancement | 6<br>Steam Injection with Mechanical Mixing | 7<br>Soil Excavation and Groundwater Removal with Sump Pumps |
|---|---|---|---|---|---|---|---|---|---|
| **Clean Air Act** | 42 USC Secs 7401 7642 | | | | | | | | |
| A Prevention of Significant Deterioration Requirements | 40 CFR 52 | NA | NA | NA | NA | NA | NA | NA | NA |
| B National Emission Standards for Hazardous Air Pollutants | 40 CFR 61 | NA | NA | NA | NA | R/Y | R/Y | R/Y | R/Y |
| **Safe Drinking Watr Act** | | | | | | | | | |
| Undergrund Inspection Control Program Class V Wells | 40 CFR 146 5 | NA | NA | NA | NA | NA | NA | R/Y | NA |
| **DOE Orders** | | | | | | | | | |
| General Environmental Protection Program | 5400 1 | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y |
| Environmental Compliance Issue Coordination | 5400 2A | NA | NA | NA | NA | NA | NA | NA | NA |
| Radiation Protection of the Public and Environment | 5400 5 | NA | NA | NA | NA | NA | NA | NA | C/Y |
| Environment Safety and Health Programs for DOE Operations | 5480 1B | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y |
| Radioactive Waste Management | 5820 2A | NA | NA | NA | NA | NA | NA | NA | C/Y |
| Hazardous and Radioactive Mixed Hazardous Waste Management | 5400 3 | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y |
| Environmental Protection Safety and Health Protection Standards | 5480 4 | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y |

Endnotes

A = Applicable
R = Relevant and Appropriate
NA = Not an ARAR
C = Considered
Y = in compliance or can be in compliance
N = not in compliance/standard exceeded

Table D 2
Potential State
Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives

| Standard Requirement Criteria or Limitation | Citation | 0 No Action | Institutional Controls without French Drain | Institutional Controls with French Drain | Modified French Drain with Additional Extraction Wells | 4 Groundwater Pumping and Soil Vapor Extraction | Groundwater Pumping and SVE with Thermal Enhancement | 6 Steam Injection with Mechanical Mixing | Soil Excavation and Groundwater Removal with Sump Pumps |
|---|---|---|---|---|---|---|---|---|---|
| **Colorado Hazardous Waste Act and State Hazardous Waste Siting Act** | CRS § 25 15 101 et seq<br>25 15 200-et seq<br>25 15 301 et seq | | | | | | | | |
| Hazardous Waste Management Regulations Identification and Listing of Hazardous Waste | 6 CCR 1007 3<br>Part 261 | R/Y | R/Y | R/Y | R/Y | $A^1$/Y | $A^1$/Y | $A^1$/Y | $A^1$/Y |
| Standards Applicable to Generators of Hazardous Waste | 6 CCR 1007 3<br>Part 262 | R/Y | R/Y | R/Y | R/Y | $A^1$/Y | $A^1$/Y | $A^1$/Y | $A^1$/Y |
| Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities | 6 CCR 1007 3<br>Part 264 | R/Y | R/Y | R/Y | R/Y | $A^1$/Y | $A^1$/Y | $A^1$/Y | $A^1$/Y |
| Temporary Unit | 6 CCR 1007 3 264 553 | NA | NA | NA | NA | A/Y | A/Y | A/Y | A/Y |
| Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage and Disposal Facilities | 6 CCR 1007 3<br>Part 265 | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y |
| Interim Status Corrective Action Orders | 6 CCR 1007 3 265 5 | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | A/Y |
| Corrective Action Management Unit (CAMU) | 6 CCR 1007 3 264 552 | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | A/Y |
| Land Disposal Restrictions | 6 CCR 1007 3<br>Part 268 | NA | NA | NA | NA | $A^2$/Y | $A^2$/Y | $A^2$/Y | $A^2$/Y |
| **Colorado Solid Waste Disposal Sites and Facilities Act** | CRS § 30-20-100 5 et seq | | | | | | | | |
| Colorado Solid Waste Disposal Sites and Facilities Regulations | 6 CCR 1007 2 2 1 15 2 5 5 and 2 5 7 | NA | NA | NA | NA | $A^2$ | $A^2$ | $A^2$ | $A^2$ |
| **Colorado Water Quality Control Act** | CRS 24-4-103(3) and (8) | | | | | | | | |
| A Effluent Limitations | 5 CCR 1002 10 1 4 | NA | NA | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y |
| B Basic Standards and Methodologies for Surface Water Quality | 5 CCR 1002-8<br>3 1 0 et seq | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y |
| C Classifications and Water Quality Standards for Groundwater and Basic Standards | 6 CCR 1007 3 5 CCR 1002 8 3 11 5 3 11 8 | C/N | C/N | C/Y | C/Y | C/Y | C/Y | C/Y | C/Y |

1 Applies to new treatment system
2 Applies to residuals of treatment system such as spent carbon HEPA filte or o exchange

**Table D 2**
**Potential State**
**Action Specific ARARs and TBCs for Proposed Remedial Action Alternatives**

| Standard Requirement Criteria or Limitation | Citation | 0<br>No Action | 1<br>Institutional Control without French Drain | 2<br>Institutional Controls with French Drain | 3<br>Modified French Drain with Additional Extraction Well | 4<br>Groundwater Pumping and Soil Vapor Extraction | 5<br>Groundwater Pumping and SVE with Thermal Enhancement | 6<br>Steam Injection with Mechanical Mixing | 7<br>Soil Excavation and Groundwater Removal with Sump Pumps |
|---|---|---|---|---|---|---|---|---|---|
| **Colorado Air Pollution Prevention Control Act, as amended** | CRS 25 7 112 | | | | | | | | |
| Colorado Air Pollution Control Regulations Air Pollutant Emission Notice Requirements | 5 CCR 1001 5<br>Regulation 3 Subpart A | NA | NA | NA | NA | NA | NA | NA | NA |
| State Construction Permits | 5 CCR 1001 5<br>Regulation 3 Subpart B | NA | NA | NA | NA | NA[3] | NA[3] | NA[3] | NA[3] |
| Operating Permit Program | 5 CCR 1001 5<br>Regulation 3 Subpart C | NA | NA | NA | NA | NA[3] | NA[3] | NA[3] | NA[3] |
| Control of Emissions Volatile Organic Compound | Regulation 7 General Provisions | NA | NA | NA | NA | R/Y | R/Y | R/Y | R/Y |
| **Soil Erosion Dust Blowing Act** | CRS 35 72 101 et seq | NA | NA[4] | NA | R/Y | R/Y | R/Y | R/Y | R/Y |
| **Act to Establish Power and Duties of Board of Health Department of Health** | CRS § 25 1 107 25 1 108 and 25 11 104 | NA | NA | NA | NA | NA | NA | NA | NA |
| Colorado Rules and Regulations Pertaining to Radiation Control | See below | | | | | | | | |
| A Radioactive Material Other than Source Material | 6 CCR 1007 1 1<br>Part III<br>RH 3 3 1 Schedule A | NA[5] | NA[5] | NA[5] | NA[5] | NA[5] | NA[5] | NA[5] | A/Y |
| B Standards for Protection Against Radiation | 6 CCR 1007 1<br>Part IV<br>RH 4 2 1-4 2 2 3 | NA[5] | NA[5] | NA[5] | NA[5] | NA[5] | NA[5] | NA[5] | A/Y |
| **Colorado Noise Abatement Statute** | CRS 25 12 101 et seq | NA | NA | NA | A/Y | A/Y | A/Y | A/Y | A/Y |
| Storage Tank Facility Owner/Operator Guidance Documents | Colorado Department of Health December 1992[1] | NA | NA | NA | NA | NA | NA | NA | NA |
| **State Engineers Authorities** | | | | | | | | | |
| Colorado Water Well & Pump Installation Regulations | CRS 37 91 101 112<br>2CRR402 2 | NA | NA | NA | C/Y | C/Y | C/Y | C/Y | C/Y |

3 Construction requirements do not apply to treatment alternative source (without consideration of other sources)· although some chemicals could trigger a requirement for an operating permit, substantive requirements are found in Regulation 7 for RACT
4 Minimal soil disturbance french drain remains in place
5 Assumes no action that would newly disturb rocks or soil

Table D 3
Potential Federal and State
Location Specific ARARs and TBCs for Proposed Remedial Action Alternatives

| Standard Requirement, Criteria, or Limitation | Citation | No Action | Institutional Controls without French Drain | Institutional Controls with French Drain | Modified French Drain with Additional Extraction Wells | Groundwater Pumping and Soil Vapor Extraction | [illegible] Groundwater Pumping with [illegible] | Steam Injection with Mechanical Mixing | Soil Excavation and Groundwater Removal [illegible] |
|---|---|---|---|---|---|---|---|---|---|
| **Resource Conservation and Recovery Act (RCRA)** | 42 USC Sec 6901 | | | | | | | | |
| General Facility Standards | 40 CFR Part 264 Subpart B 264 18(b) | NA | NA | NA | NA | NA | NA | NA | NA |
| **Endangered Species Act** | 16 USC 1531 1543 | | | | | | | | |
| Endangered and Threatened Wildlife and Plants | 50 CFR Part 17 | NA | NA | NA | NA | NA | NA | NA | NA |
| **National Historic Preservation Act** | 16 USC Sec 470 | | | | | | | | |
| Protection of Historic and Cultural Properties | 36 CFR Part 800 | NA | NA | NA | NA | NA | NA | NA | NA |
| **Historic Sites** | 16 USC Secs 461-467 | | | | | | | | |
| National Natural Landmarks Program | 36 CFR Part 62 | NA | NA | NA | NA | NA | NA | NA | NA |
| **Archaeological Resources Protection Act** | 16 USC 470aa 11 | | | | | | | | |
| Protection of Archaeological Resources Uniform Regulations | 36 CFR Part 296 | NA | NA | NA | NA | NA | NA | NA | NA |
| **Preservation of American Antiquities Act**<br>Preservation of American Antiquities | 16 USC 431-433<br>43 CFR Part 3 | NA | NA | NA | NA | NA | NA | NA | NA |
| **Executive Orders** | | | | | | | | | |
| Executive Order on Floodplain Management<br>Compliance with Floodplain/Wetlands Environmental Review Requirements | Executive Order No 11988<br>10 CFR Part 1022 | NA | A/Y | NA | NA | NA | NA | NA | NA |
| Executive Order on Protection of Wetlands<br>Compliance with Floodplain/Wetlands Environmental Review Requirements | Executive Order No 11990<br>10 CFR Part 1022 | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y |
| Historical Prehistorical and Archaeological Resources Act | CRS 24-65 1 104<br>CRS 24-65 1 201 202 and 302 | NA | NA | NA | NA | NA | NA | NA | NA |
| State Register of Historic Places Act | CRS 24-80-401 et seq<br>CRS 24-80 1 101 et seq | NA | NA | NA | NA | NA | NA | NA | NA |
| Non game Endangered or Threatened Species Conservation Act | CRS 33 2 101 et.seq | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y |

**Table D-3**
**Potential Federal and State**
**Location Specific ARARs and TBCs for Proposed Remedial Action Alternatives**

| Standard, Requirement, Criteria, or Limitation | Citation | No Action | [illegible] Controls with [illegible] French Drain | [illegible] Controls with the French Drain | [illegible] French Drain with Additional Extraction Wells | Groundwater Pumping and Soil Vapor Extraction | Groundwater Pumping and VE with [illegible] | [illegible] Injection with Mechanical Mix | [illegible] Excavation and Groundwater Removal with [illegible] |
|---|---|---|---|---|---|---|---|---|---|
| **Resource Conservation and Recovery Act (RCRA)** | 42 USC Sec 6901 | | | | | | | | |
| General Facility Standards | 40 CFR Part 264 Subpart B 264 18(b) | NA | NA | NA | NA | NA | NA | NA | NA |
| **Endangered Species Act** | 16 USC 1531 1543 | | | | | | | | |
| Endangered and Threatened Wildlife and Plants | 50 CFR Part 17 | NA | NA | NA | NA | NA | NA | NA | NA |
| **National Historic Preservation Act** | 16 USC Sec 470 | | | | | | | | |
| Protection of Historic and Cultural Properties | 36 CFR Part 800 | NA | NA | NA | NA | NA | NA | NA | NA |
| **Historic Sites** | 16 USC Secs 461-467 | | | | | | | | |
| National Natural Landmarks Program | 36 CFR Part 62 | NA | NA | NA | NA | NA | NA | NA | NA |
| **Archaeological Resources Protection Act** | 16 USC 470aa-11 | | | | | | | | |
| Protection of Archaeological Resources Uniform Regulations | 36 CFR Part 296 | NA | NA | NA | NA | NA | NA | NA | NA |
| **Preservation of American Antiquities Act**<br>Preservation of American Antiquities | 16 USC 431-433<br>43 CFR Part 3 | NA | NA | NA | NA | NA | NA | NA | NA |
| **Executive Orders** | | | | | | | | | |
| Executive Order on Floodplain Management | Executive Order No 11988 | | | | | | | | |
| Compliance with Floodplain/Wetlands Environmental Review Requirements | 10 CFR Part 1022 | NA | A/Y | NA | NA | NA | NA | NA | NA |
| Executive Order on Protection of Wetlands | Executive Order No 11990 | | | | | | | | |
| Compliance with Floodplain/Wetlands Environmental Review Requirements | 10 CFR Part 1022 | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y | A/Y |
| Historical Prehistorical and Archaeological Resources Act | CRS 24-65 1 104<br>CRS 24-65 1 201 202 and 302 | NA | NA | NA | NA | NA | NA | NA | NA |
| State Register of Historic Places Act | CRS 24-80-401 et seq<br>CRS 24-80 1 101 et seq | NA | NA | NA | NA | NA | NA | NA | NA |
| Non game Endangered or Threatened Species Conservation Act | CRS 33 2 101 et.seq | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y | R/Y |